Liberty Reservoir
Small Watershed Action Plan

Volume II

Prepared for:

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APPENDIX E:

Liberty Reservoir Watershed Characterization Report

(PB 2015)

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Watershed Characterization Report

Prepared for:

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FINAL

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List of Acronyms and Abbreviations

AMA	Agricultural Management Assistance
ATV	All-Terrain Vehicle
BIBI	Benthic Index of Biotic Integrity
BMC	Baltimore Metropolitan Council
BMP	Best Management Practice
BOD	Biological Oxygen Demand
BSID	Biological Stressor Identification
CAFO	Confined Animal Feeding Operation
CBP	Chesapeake Bay Program
CEM	Channel Evolution Model
COD	Chemical Oxygen Demand
CREP	Conservation Reserve Enhancement Program
CRP	Community Reforestation Program
CSO	Combined Sewer Overflow
CSP	Conservation Stewardship Program
CWA	Clean Water Act
CWP	Center for Watershed Protection
DNR	Department of Natural Resources
EPS	Environmental Protection and Sustainability
EQIP	Environmental Quality Incentives Program
ESD	Environmental Site Design
GIS	Geographic Information System
HSG	Hydrologic Soil Group
HIS	Hotspot Site Investigation
IR	Integrated Report
ISI	Institutional Site Investigation
LA	Load Allocations
LU/LC	Land Use/ Land Cover
MACS	Maryland Agricultural Water Quality Cost-Share
MALPF	Maryland Agricultural Land Preservation Foundation
MBSS	Maryland Biological Stream Survey
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MET	Maryland Environmental Trust
MPN	Most Probable Number
NAIP	National Agriculture Imagery Program
NEA	Natural Environmental Area
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NSA	Neighborhood Source Assessment
OIT	Office of Information Technology

PAA	Pervious Area Assessment
PCB	Polychlorinated Biphenyl
PSI	Pollution Severity Index
ROI	Restoration Opportunity Index
RWPC	Reservoir Watershed Protection Committee
SCA	Stream Corridor Assessment
SCWQP	Soil Conservation and Water Quality Plans
SHA	State Highway Administration
SSO	Sanitary Sewer Overflow
SSURGO	Soil Survey Geographic database
SW	Stormwater
SWAP	Small Watershed Action Plan
SWM	Stormwater Management
TMDL	Total Maximum Daily Loads
TP	Total Phosphorus
TSS	Total Suspended Solids
URDL	Urban/Rural Demarcation Line
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USSR	Unified Subwatershed and Site Reconnaissance
USLE	Universal Soil Loss Equation
WHIP	Wildlife Habitat Incentive Program
WLA	Water Load Allocations
WRAS	Watershed Restoration Action Strategy
WRE	Water Resources Element
WQA	Water Quality Analysis
WWTP	Waste Water Treatment Plant

CHAPTER 1: INTRODUCTION

1.1 Purpose

The purpose of the Liberty Reservoir Watershed Characterization Report is to:

1. Summarize the factors that may affect the water quality of the Liberty Reservoir watershed such as landscape, geomorphology, hydrology, and biological characteristics;
2. Explain the current conditions of Liberty Reservoir watershed and its natural resources;
3. Describe human impacts on the watershed such as development and land use; and
4. Identify restoration and preservation strategies appropriate for accomplishing watershed improvement goals.

The observations and conclusions presented in this watershed characterization report will be used to develop a Small Watershed Action Plan (SWAP) for the Liberty Reservoir watershed.

1.2 Watershed Location and Scale

The Liberty Reservoir watershed is located in the Piedmont Plateau physiographic province of Maryland and includes portions of Baltimore and Carroll counties. Only the portion of the watershed that resides in Baltimore County east of the reservoir, identified as SWAP Area S, is addressed in this watershed characterization report and SWAP. Herein, it will be referred to as the Liberty Reservoir watershed (see Figure 1-1). The Liberty Reservoir watershed has an extent of approximately 17,502 acres which includes the land area (16,449 acres) as well as the Baltimore County portion of the Liberty Reservoir (1,053 acres). The land area acreage has been used for analysis throughout this study. The watershed drains the eastern side of the reservoir watershed to the impoundment of the Liberty Reservoir, after which it continues to the Patapsco River and the Chesapeake Bay. The Liberty Reservoir watershed is bordered to the east by the Loch Raven Reservoir watershed and the Gwynns Falls watershed, to the south by the Patapsco River Lower North Branch watershed, and to the west by Carroll County and the western portion of the Liberty Reservoir watershed.

The Liberty Reservoir watershed was subdivided into smaller drainage areas or subwatersheds, which are listed in Table 1-1 with respective drainage areas in acreage and square miles. The three most northern subwatersheds, Deep Run-Liberty, Aspen Run, and Board Run, were combined into one subwatershed herein referred to as Board-Aspen Run. In addition to characterizing the entire watershed, analyses were conducted on a subwatershed scale to provide detailed information for smaller areas and to focus restoration and preservation efforts. Also, success of restoration efforts can be more easily monitored and measured on this smaller scale. Figure 1-2 shows the 14 subwatersheds comprising the Liberty

Reservoir watershed. Methods for the delineation of the watersheds and subwatersheds are described in further detail in Chapter 2.

Figure 1-1: Location of Liberty Reservoir Watershed

Table 1-1: Liberty Reservoir Subwatershed Areas

Subwatershed	Area (Acres)	Area (Sq Miles)
Board-Aspen Run	758	1.18
Cliffs Branch	3,142	4.91
Glen Falls Run	2,059	3.22
Liberty Reservoir-B	638	1.00
Keyser Run	1,006	1.57
Liberty Reservoir-E	280	0.44
Norris Run	1,790	2.80
Liberty Reservoir-C	391	0.61
Timber Run	932	1.46
Cooks Branch	786	1.23
Liberty Reservoir-F	2,014	3.15
Chimney Branch	439	0.69
Liberty Reservoir-A	786	1.23
Locust Run	1,428	2.23
Total	***16,449***	***25.70***

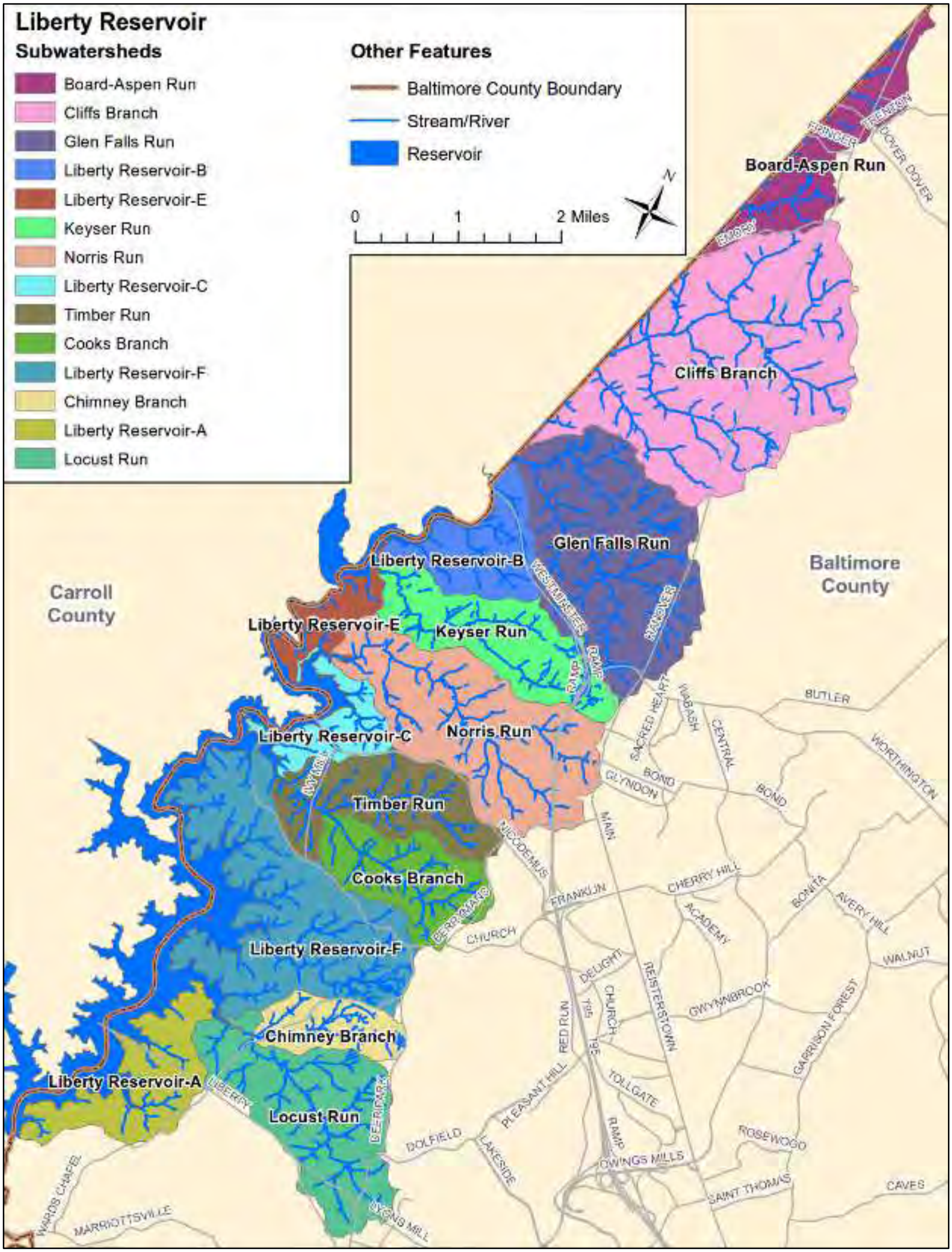

Figure 1-2: Liberty Reservoir Subwatersheds

1.3 Report Organization

The Liberty Reservoir Watershed Characterization report is organized into the following six chapters:

Chapter 1 – Explains the purpose of the report and the location and scope of the watershed characterization.

Chapter 2 – Summarizes characteristics related to landscape and land use that may affect natural resources and water quality in the Liberty Reservoir watershed. This chapter contains landscape information related to natural features such as geology, topography, soils, forest cover, and streams. Information pertaining to human influence on landscape is also discussed, including land use, population, impervious cover amount, water distribution, and stormwater infrastructure.

Chapter 3 – Discusses water quality and quantity conditions in the watershed based on available monitoring data and stream assessment data.

Chapter 4 – Describes the upland assessments conducted to identify pollutant sources and restoration opportunities for four assessment categories: neighborhoods, hotspots, institutions, and pervious areas.

Chapter 5 – Presents restoration and preservation strategies appropriate for accomplishing watershed goals developed by the community and the Liberty Reservoir SWAP Steering Committee.

Chapter 6 – Lists the references consulted during the development of this report.

CHAPTER 2: LANDSCAPE AND LAND USE

2.1 Introduction

This chapter discusses land cover and land use in the Liberty Reservoir watershed describing characteristics of both the natural land surface as well as development activities taking place within the watershed. Natural characteristics such as soil type and development related features such as impervious cover strongly influence the quantity and quality of watershed runoff. For example, the infiltration capacity of soils found on pervious ground affects the amount and rate at which precipitation will be absorbed into the ground surface; impervious surfaces, such as buildings and paved areas, impede rainfall infiltration, which can lead to flooding, erosion, and eventually a decrease in groundwater supply. In addition, the type and extent of pollutants carried by stormwater are affected by land use characteristics. Residential or agricultural areas may contribute fertilizers and pesticides to stormwater runoff. Depending on the land use activities taking place, developed areas may transmit pollutants such as trash, bacteria from livestock and pet waste, and chemicals directly to receiving water bodies if there is an inadequate vegetative buffer to filter out the pollutants before the runoff reaches the water. The information presented in this chapter provides the physical setting and background necessary to evaluate watershed elements including water quality, natural resources, restoration, and management.

2.2 Natural Landscape

Natural land surface characteristics relevant to watershed properties and processes are described in the following sections. These topics include climate, watershed delineation, topography, geology, soil properties, forest cover, and stream systems.

2.2.1 Climate

Climate is an important consideration when evaluating water quality, because it can influence soil and erosion processes, stream flow patterns, and topography. Climate affects vegetative growth and determines the species composition of terrestrial and aquatic life of a region. While rainfall patterns are an important component of the hydrology of a watershed and can affect watershed management strategies.

The Liberty Reservoir region has a humid continental climate with four distinct seasons. It has a relatively temperate climate due to the combined effects of the Appalachian Mountains to the west and the Chesapeake Bay and Atlantic Ocean to the east. Average annual rainfall in Baltimore, Maryland is 41.88 inches based on 30 years of data (1981-2010) (NOAA, 2013a). Rainfall is uniformly distributed throughout the year, with monthly averages ranging from 2.90 inches for February to 4.07 inches for July. Most snowfall occurs in December, January, February, and March with an average annual snowfall of 20.1 inches based on 30 years of data (1981-2010) (NOAA, 2013b).

2.2.2 Watershed Delineation

A watershed-based approach for evaluating water quality conditions and improvement potential requires determining the drainage areas that contribute runoff and groundwater to a specific water body. Drainage areas vary greatly in size depending on the scale of the stream system of interest. Drainage areas for large river, estuary, and lake systems are typically on the order of several thousand square miles and are often referred to as basins. The Chesapeake Bay basin covers over 64,000 square miles, which includes over 100,000 tributaries and spans across portions of six different states (CBP, 2012). Basins consist of smaller sub-basins, which refer to drainage areas on the order of several hundred square miles and may consist of one or more major stream networks. Maryland has 13 sub-basins including the Patapsco/Back River sub-basin, which encompasses the study area for this report. Sub-basins are further subdivided into watersheds and then subwatersheds, which are the most commonly used and practical hydrologic units for management and restoration purposes. There are 138 state-defined watersheds (called 8-digit watersheds) in Maryland, ranging in size from 20 to 100 square miles, and these are comprised of over 1,100 subwatersheds (called 12-digit watersheds) identified by the Maryland Department of Natural Resources (DNR). A subwatershed refers to the drainage area of a specific stream and typically covers 10 square miles or less (DNR, 2005).

There are 14 8-digit watersheds in Baltimore County. The 8-digit Liberty Reservoir watershed (02-13-09-07) is approximately 164 square miles and encompasses portions of Baltimore and Carroll counties. The portion of the Liberty Reservoir 8-digit watershed located in Baltimore County is approximately 26 square miles (16,449 acres). For planning and management purposes, the Liberty Reservoir watershed has been further subdivided into 14 subwatersheds by Baltimore County, as illustrated in Figure 1-2. Watershed delineations were provided by the Baltimore County Office of Information Technology (OIT) via spatial data based on 1998 Maryland state-defined 8-digit and 12-digit watershed information.

2.2.3 Topography

The topography of a region describes the shape of the land including locations and elevations of surface features such as ridges and valleys. Land shape characteristics such as steepness affect the direction and magnitude of surface water flows, degree of soil erosion, and suitability for development. Land surface topography affects water quality as steeper slopes are more prone to overland flow and soil erosion resulting in a greater potential to generate pollutants in runoff. Soil slope data for the Liberty Reservoir watershed was obtained from the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database (USDA, 2013) and divided into the following five slope ranges, which were derived from slope classification definitions in the U.S. Department of Agriculture (USDA) *Soil Survey Manual* (USDA, 1993).

- Nearly level (0 to 3% slopes)
- Gently sloping, undulating (3 to 8% slopes)
- Strongly sloping, rolling (8 to 15% slopes)
- Moderately steep, hilly (15 to 25% slopes)
- Steep (> 25% slopes)

Table 2-1 provides a summary of the percent breakdown of soil slopes by watershed. The Liberty Reservoir watershed has a variety of slope classifications. Overall, the watershed has a significant portion of soil slopes in the strongly sloping (34%) and gently sloping (33%) categories. Overall, the moderately steep and steep categories are located near the streams and the nearly level and gently sloping categories are located in the upland portion of the watershed. Based on soil slope alone, the Liberty Reservoir watershed is prone to erosion by overland flow; however, the degree of erosion is also dependent on soil type and land use/land cover. The subwatersheds with the flattest topography are Board-Aspen Run and Cliffs Branch, both with approximately 16% nearly level land. Liberty Reservoir-A has the highest percentage of steep slopes at 17% followed by Liberty Reservoir-E with a percentage of steep soils of 14%. Soil slopes within Liberty Reservoir are shown in Figure 2-1.

Table 2-1: Liberty Reservoir Slope Classification by Subwatershed

	SLOPE CATEGORY %				
Subwatershed	**Nearly Level (0-3%)**	**Gently sloping, undulating (3-8%)**	**Strongly sloping, rolling (8-15%)**	**Moderately steep, hilly (15-25%)**	**Steep (>25%)**
Board-Aspen Run	15.89	52.03	23.56	6.92	1.60
Cliffs Branch	15.88	36.16	31.44	11.03	5.48
Glen Falls Run	9.65	32.46	33.67	18.98	5.24
Liberty Reservoir-B	3.22	24.70	36.11	35.47	0.50
Keyser Run	6.00	34.67	36.08	18.02	5.23
Liberty Reservoir-E	0.23	11.81	41.89	31.71	14.36
Norris Run	6.44	34.21	37.34	17.86	4.14
Liberty Reservoir-C	0.39	19.48	39.35	29.12	11.66
Timber Run	7.50	23.16	43.17	21.83	4.33
Cooks Branch	8.18	31.60	34.19	17.22	8.81
Liberty Reservoir-F	3.24	29.29	36.60	22.37	8.49
Chimney Branch	7.00	26.07	38.76	28.17	0.00
Liberty Reservoir-A	1.05	27.49	28.74	25.64	17.08
Locust Run	7.88	44.11	29.40	15.14	3.47
Total	***8.36***	***33.15***	***34.13***	***18.47***	***5.89***

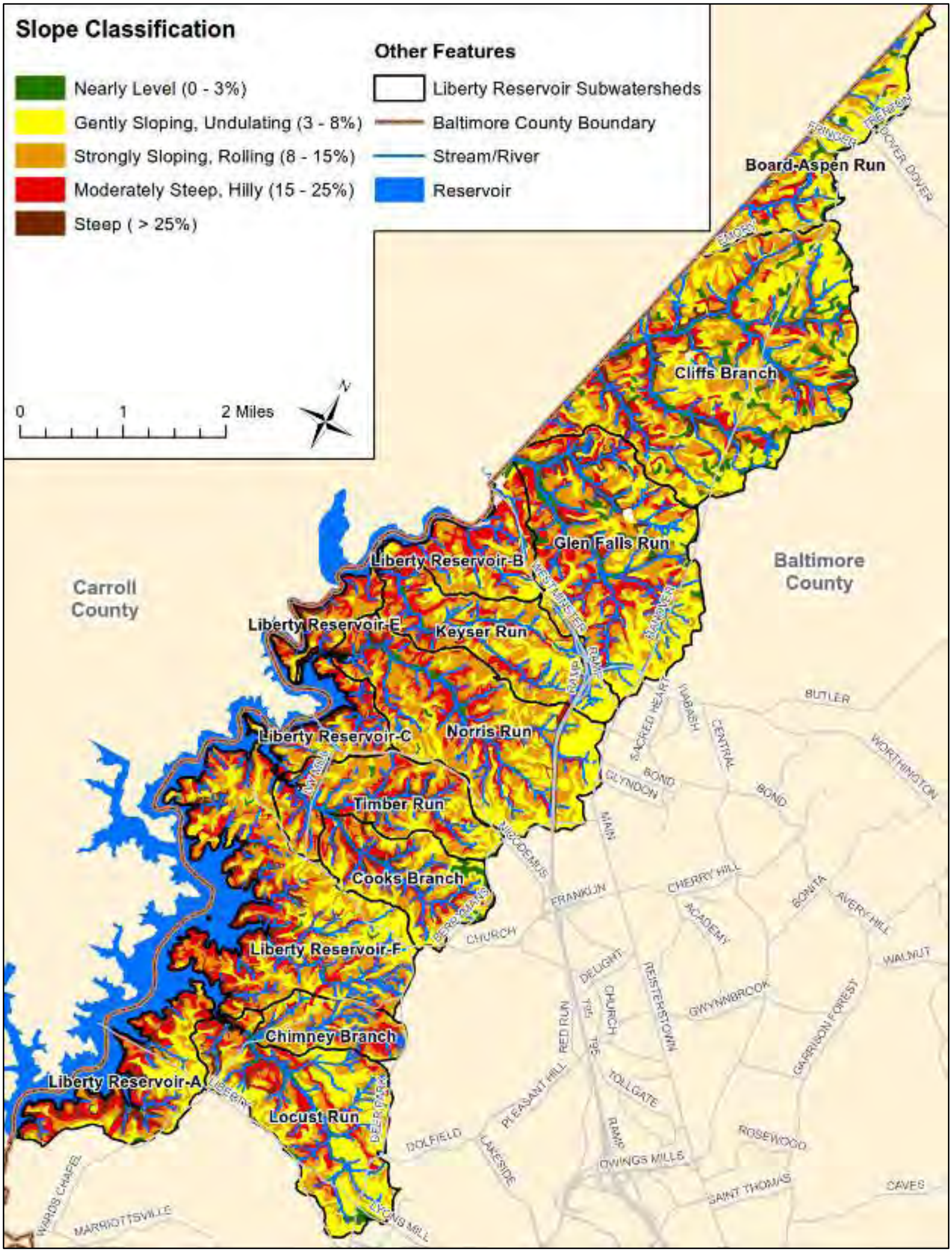

Figure 2-1: Liberty Reservoir Topography based on Soil Slopes

2.2.4 Geology

The geology of an area affects the chemical composition of surface water and groundwater, as well as groundwater and well recharge rates. It is also relevant to soil formation and influences the buffering capacity of pollutants to water bodies in developed areas. Consequently, geology often has a close correlation to water quality.

The Liberty Reservoir watershed is located in the Upland Section of the Piedmont Plateau Province of Maryland. Soils in this region consist of very deep, moderately sloping, well drained upland soils. The dominant piedmont soils in the Baltimore area consist of Ultic Hapludalfs. The region contains contrasting rock types, such as highly metaphorphosed sedimentary and igneous rocks of volcanic origin as well as granitic plutons and pegmatites, which create a distinctive topography (MGS, 2014).

The entire watershed falls under the Harford Plateaus and Gorges Region of the Piedmont Plateau Province. The physiographic characteristics of this region are gently rolling or moderately hilly landscapes. Physiographic regions are further subdivided into districts. The entire Liberty Reservoir watershed falls within the Hampstead Upland District which is characterized by rolling to hilly uplands interrupted by steep-walled gorges producing distinctive hills, valleys, and ridges (MGS, 2008). The main geological formations of the Liberty Reservoir watershed consist primarily of coarse-grained quartz schist and fine- to medium-grained mafic schists (MGS, 2008). Within Hampstead Upland District, the watershed has two unique areas: the Soldiers Delight Area, which is underlain with Serpentinite and the Upper Patapsco River Gorge Area, which includes the narrow, step gorge of the upstream Patapsco River (MGS, 2008). The geology is closely correlated with water quality and affects the buffering of pollution to stream systems in developed areas.

2.2.5 Soils

Soil characteristics are an important consideration when evaluating water quantity and quality in streams and rivers. Soil type and moisture content impact how land may be used and its potential for vegetation and habitat. Soil conditions are also evaluated for projects aimed at improving water quality and habitat.

Soils data including hydrologic soil groups and soil erodibility for the Liberty Reservoir watershed was obtained from spatial data provided by the NRCS SSURGO database (USDA, 2013).

2.2.5.1 Hydrologic Soil Groups

The NRCS classifies soils into four hydrologic soils groups (HSG) based on their runoff potential and infiltration rates. Soils with high runoff potential have low infiltration capacity and tend to cause overland flow instead of allowing stormwater to infiltrate. Infiltration rates are highly variable among soil types and are influenced by disturbances to the soil profile such as land development activities. For example, urbanization on land composed of high infiltration soils (such as sands and gravels) will greatly increase runoff from the pre-development runoff rate. Whereas development on land composed of low infiltration soils (such as silts and clays) will have less of an impact on runoff.

The four hydrologic soil groups range from A to D, lowest runoff potential to highest, respectively. Brief descriptions of each hydrologic soil group are provided below. Further explanation can be found in chapter 7 of the USDA/NRCS publication, *National Engineering Handbook- Hydrology Chapters* (USDA & NRCS, 2009).

- **Group A** soils include sand, loamy sand, or sandy loam types. These soils have low runoff potential when thoroughly wet and a high infiltration rate. This type of soil generally consists of sands and gravels, typically have less than 10 percent clay, and have gravel or sand textures. These soils have a high rate of water transmission.
- **Group B** soils include well aggregated loam, silt loam, or sandy clay loam. These soils have a moderately low runoff potential when thoroughly wet. These soils generally contain between 10 to 20 percent clay and 50 to 90 percent sand with a loamy sand or sandy loam texture. Water transmission through these soils is moderate.
- **Group C** soils include silt loam, sandy clay loam, clay loam, and silty clay loam textures. These soils have a moderately high runoff potential when thoroughly wet. This soil typically contains between 20 to 40 percent clay and less than 50 percent sand. Water transmission through these soils is low and somewhat restricted.
- **Group C/D** soils are wet Group C soils, including silt loam, sandy loam, clay loam, and silty clay loam. These wet soils are placed in a dual category due to the presence of a water table within 24 inches of the surface. The first letter refers to the drained condition while the second letter describes the undrained condition. Only wet soils that can be adequately drained are placed into dual categories.
- **Group D** soils include clayey textures. These soils have high runoff potential when thoroughly wet. These soils generally contain greater than 40 percent clay and less than 50 percent sand. These consist mainly of clays with high swell potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. Water transmission through this soil is very restricting with very low infiltration rates.

As shown in Table 2-2 and Figure 2-2, most of the Liberty Reservoir subwatersheds possess similar hydrologic soil group characteristics in both the upland and bottomland areas with the exception being in the Soldiers Delight Area. Nearly 65% of the Liberty Reservoir watershed falls into hydrologic soil group B which has a moderate infiltration rate and therefore, relatively low runoff potential. Approximately 16% of the watershed falls into soil group D exhibiting low infiltration and a high runoff potential. The D soils group is generally found along the stream valley and bottomlands of each subwatershed and in the Soldiers Delight Area. There are no soils within the watershed that fall into soil group A, which are characterized by high infiltration rates and low runoff potential.

Table 2-2: Liberty Reservoir Hydrologic Soil Groups

	Hydrologic Soil Group (%)					
Subwatershed	A	B	C	C/D	D	Water
Board-Aspen Run	0.0	67.5	9.6	0.0	22.6	0.4
Cliffs Branch	0.0	67.4	10.4	0.0	22.1	0.1
Glen Falls Run	0.0	71.0	13.4	0.0	15.3	0.3
Liberty Reservoir-B	0.0	76.6	10.6	0.0	7.7	5.1
Keyser Run	0.0	69.2	17.8	0.0	13.0	0.0
Liberty Reservoir-E	0.0	60.8	25.1	0.0	3.4	10.8
Norris Run	0.0	63.4	23.1	0.0	13.5	0.0
Liberty Reservoir-C	0.0	86.1	10.9	0.0	2.8	0.3
Timber Run	0.0	67.6	22.4	0.0	10.0	0.0
Cooks Branch	0.0	63.9	19.9	4.7	11.5	0.0
Liberty Reservoir-F	0.0	59.7	20.1	5.9	11.7	2.6
Chimney Branch	0.0	9.6	30.9	15.9	43.6	0.0
Liberty Reservoir-A	0.0	93.6	1.0	2.3	0.9	2.1
Locust Run	0.0	44.2	18.9	15.9	20.9	0.2
Total	***0.0***	***64.8***	***16.0***	***2.9***	***15.5***	***0.9***

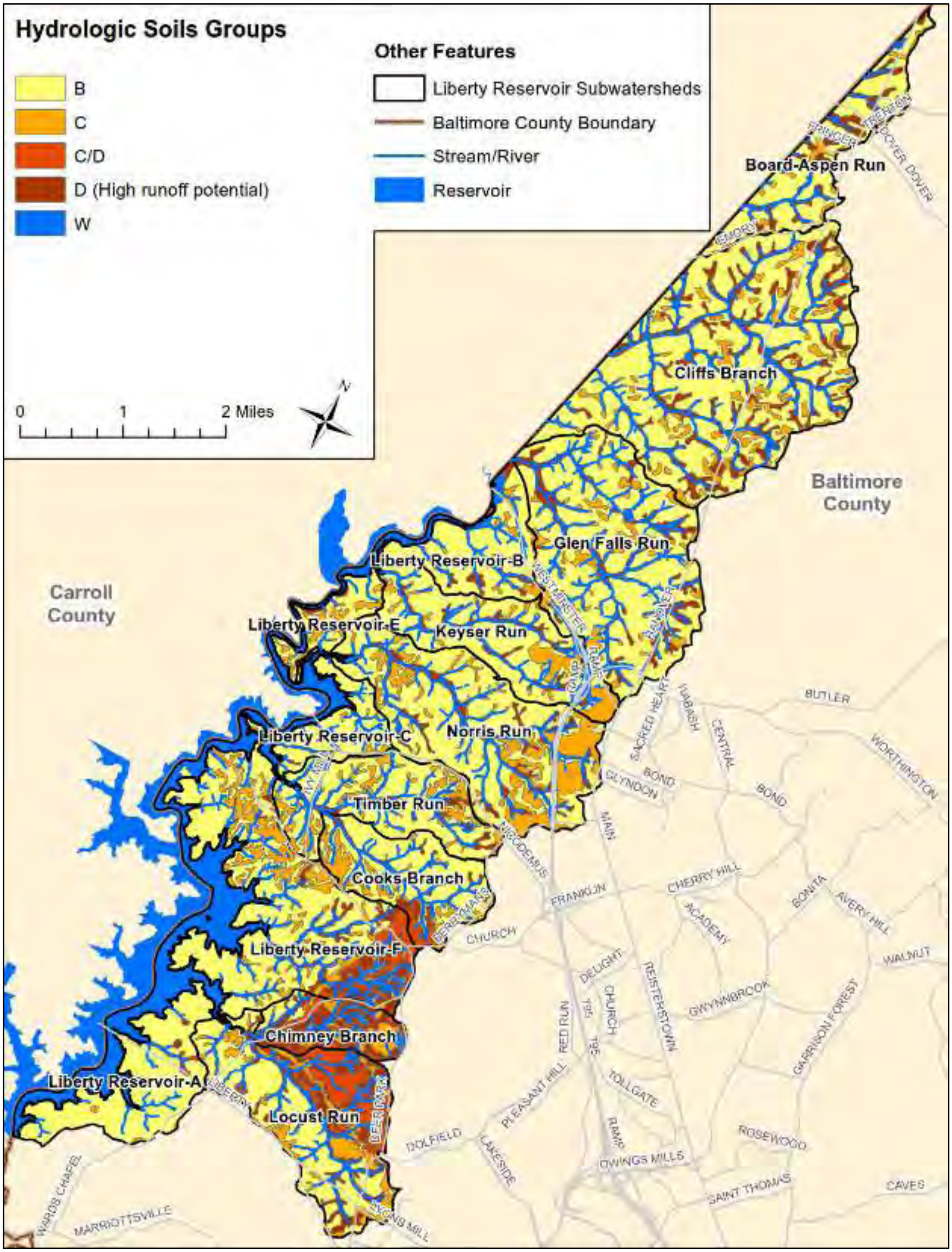

Figure 2-2: Liberty Reservoir Hydrologic Soils Groups

2.2.5.2 Erodibility

Erodibility is the susceptibility of soil to erosion. It is quantified by the K factor, which is used in the Universal Soil Loss Equation (USLE) developed by USDA's Agricultural Research Service to estimate the rate of erosion and soil loss for a particular site. Soil erodibility is determined based on the physical and chemical properties of the soil, which represent how strongly soil particles cohere to one another. Soils with low K factors indicate low erodibility or high resistance to detachment, and soils with high K factors indicate high erodibility potential. For example, soils high in clay content are the least erodible with K values of about 0.05 to 0.15, and soils with high silt content are the most erodible with K values often greater than 0.4 (IWR, 2002).

Table 2-3 summarizes soil erodibility values in the Liberty Reservoir watershed by subwatershed. Erodibility K factors range from 0 to 0.49 and were grouped into 3 categories as follows:

- Low Erodibility (0 ≤ K factor < 0.24);
- Medium Erodibility (0.24 ≤ K factor < 0.32); and
- High Erodibility (0.32 ≤ K factor < 0.49)

A portion of the soils within the SSURGO data do not have a K factor associated; these areas are conveyed in the "N/A" category as seen in Table 2-3 and Figure 2-3.

Table 2-3: Liberty Reservoir Soil Erodibility Categorization Based on K Factor

	Soil Erodibility Category (%)			
Subwatershed	Low	Medium	High	N/A
Board-Aspen Run	25.9	28.8	41.7	3.6
Cliffs Branch	36.0	28.6	27.8	7.7
Glen Falls Run	37.3	17.9	32.5	12.3
Liberty Reservoir-B	42.4	2.8	23.6	31.2
Keyser Run	32.5	17.3	31.9	18.3
Liberty Reservoir-E	43.8	0.2	3.5	52.5
Norris Run	38.5	9.6	30.7	21.2
Liberty Reservoir-C	48.4	0.0	12.4	39.2
Timber Run	29.9	8.3	35.9	25.9
Cooks Branch	21.1	12.6	27.4	38.9
Liberty Reservoir-F	26.8	8.2	22.6	42.3
Chimney Branch	18.5	29.7	16.7	35.0
Liberty Reservoir-A	20.9	17.1	35.0	27.0
Locust Run	11.9	22.5	43.7	21.8
Total	***31.1***	***17.0***	***29.5***	***22.4***

As shown in Table 2-3 and Figure 2-3, there is a significant presence of all three soil erodibility categories in the Liberty Reservoir watershed. Medium erodible soils are more evident in Board-Aspen Run, Cliffs Branch, and Chimney Branch, with approximately 29%, 29%, and 30% medium erodible soils, respectively. Highly erodible soils are the most evident in Board-Aspen Run and Locust Run (>40%). Soils within Liberty Reservoir-C have the highest percentage of soils with low erodibility. Soils with low erodibility correspond to soils with very low infiltration rates (pertaining to hydrologic soil group D). The majority of the Liberty Reservoir watershed soils have moderate infiltration rates (hydrologic soil group B) resulting in higher erodibility. Approximately 22% of the total watershed soils do not have an associated K factor in the SSURGO database.

Subwatersheds with larger percentages of highly erodible soils present the greatest potential for addressing soil conservation issues via best management practices (BMPs), such as minimizing bare soil and keeping topsoil in place. Soil erodibility data is also useful in combination with other information such as location of cropland, slope steepness, and distance from streams to determine where other BMPs, such as retirement of highly erodible cropland, are appropriate. High K factor values also serve as a warning for planning of urban activities near streams such as road construction and utility placements.

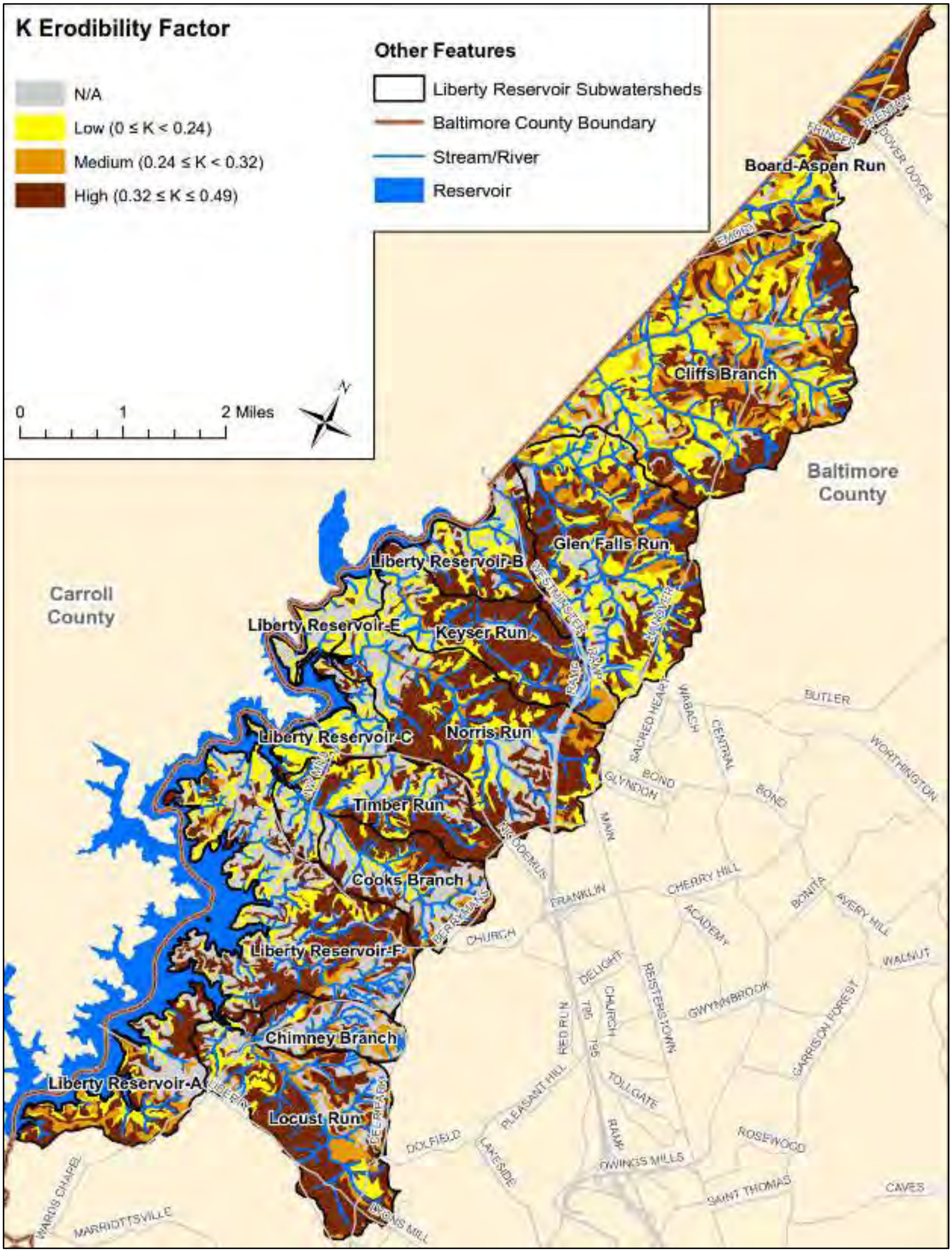

Figure 2-3: Liberty Reservoir Soil Erodibility Based on K Factor

2.2.6 Forest Cover/Forest Canopy

Forests provide the greatest protection among land cover types for water and soil quality. In pristine systems, forest and soils co-evolve, shaping the hydrologic cycle; these systems operate within a natural range of variability, assuring healthy habitat and water quality. The Liberty Reservoir watershed consisted mainly of old-growth forest prior to colonial settlement, as is true for the entire Chesapeake Bay basin. Although the watershed is relatively rural, deforestation has occurred; however, even in developed systems, forest cover can still provide many benefits such as reducing erosion potential and protecting water quality if carefully planned and conserved.

For the Liberty Reservoir watershed, forest cover and forest canopy were both examined. Forest cover implies not only the presence of a tree canopy, but also understory vegetation with little or no impervious structures. Forest canopy indicates that a tree canopy is present, but the land use beneath the canopy may be pavement, homes, turf grass, etc.

Liberty Reservoir forest cover data was obtained from the Maryland Department of Planning (MDP) 2010 land use/land cover Geographic Information System (GIS) shapefile. Forest cover included deciduous, evergreen, and mixed forest classifications. Table 2-4 lists the number of acres of forest cover for each subwatershed in the Liberty Reservoir watershed, along with the percent of the watershed that is forested. Figure 2-4 shows the distribution of forest cover within the watershed. The Liberty Reservoir watershed contains approximately 6,929 acres of forest cover, or approximately 42% of the watershed. The highest forest cover percentages are found in Liberty Reservoir-E, Timber Run, Chimney Branch, and Locust Run, all with more than 60% forest cover. The subwatersheds with the lowest forest cover percentages are Board-Aspen Run, Cliffs Branch, and Keyser Run, with 14.9%, 21.8%, and 24.7% forest cover, respectively. Board-Aspen Run and Cliffs Branch are dominated by agriculture, and although some of the land is in agricultural preservation easements, they may still offer some potential opportunity for reforestation.

Forest canopy data for the Liberty Reservoir watershed was obtained from 2007 Urban Tree Canopy Land Cover spatial data for Baltimore County. This data was created based on 2007 infrared aerial imagery and 2005 LiDAR data by the University of Vermont Spatial Analysis Laboratory. Using the MDP land use/land class data, forest canopy was superimposed to determine which land use the forest canopy presides. The land use was divided into four major categories: forest, agriculture, residential, and other. The other category consists of land uses such as commercial, industrial, institutional, bare ground, et cetera, that amount to a minor portion of the total watershed. Table 2-5 summarizes the different forest canopied areas in each sub basin as well as the total percentage of tree canopy present in each sub basin. The "other" category includes tree canopy present on commercial, institutional, industrial, transportation, water/wetlands, and open urban land. Figure 2-5 shows the distribution of forest canopy by land use throughout the watershed. Approximately 60% of the Liberty Reservoir watershed is shaded with tree canopy. The majority of the canopy resides within forest cover land use; however a significant portion of canopy is also present within residential land use.

Since the forest canopy includes coverage from multiple land uses, all of the subwatersheds have a higher percentage of forest canopy than forest cover. Notable differences are shown in Liberty Reservoir-B, Keyser Run, Liberty Reservoir-C, and Cooks Branch.

Table 2-4: Liberty Reservoir Forest Cover by Subwatershed

Subwatershed	Total Acres	Forested Acres	% Forested
Board-Aspen Run	758	113	14.9%
Cliffs Branch	3,142	685	21.8%
Glen Falls Run	2,059	906	44.0%
Liberty Reservoir-B	638	268	42.0%
Keyser Run	1,006	248	24.7%
Liberty Reservoir-E	280	170	60.9%
Norris Run	1,790	647	36.2%
Liberty Reservoir-C	391	197	50.3%
Timber Run	932	580	62.2%
Cooks Branch	786	331	42.1%
Liberty Reservoir-F	2,014	1170	58.1%
Chimney Branch	439	288	65.5%
Liberty Reservoir-A	786	465	59.2%
Locust Run	1,428	860	60.2%
Total	***16,449***	***6,929***	***42.1%***

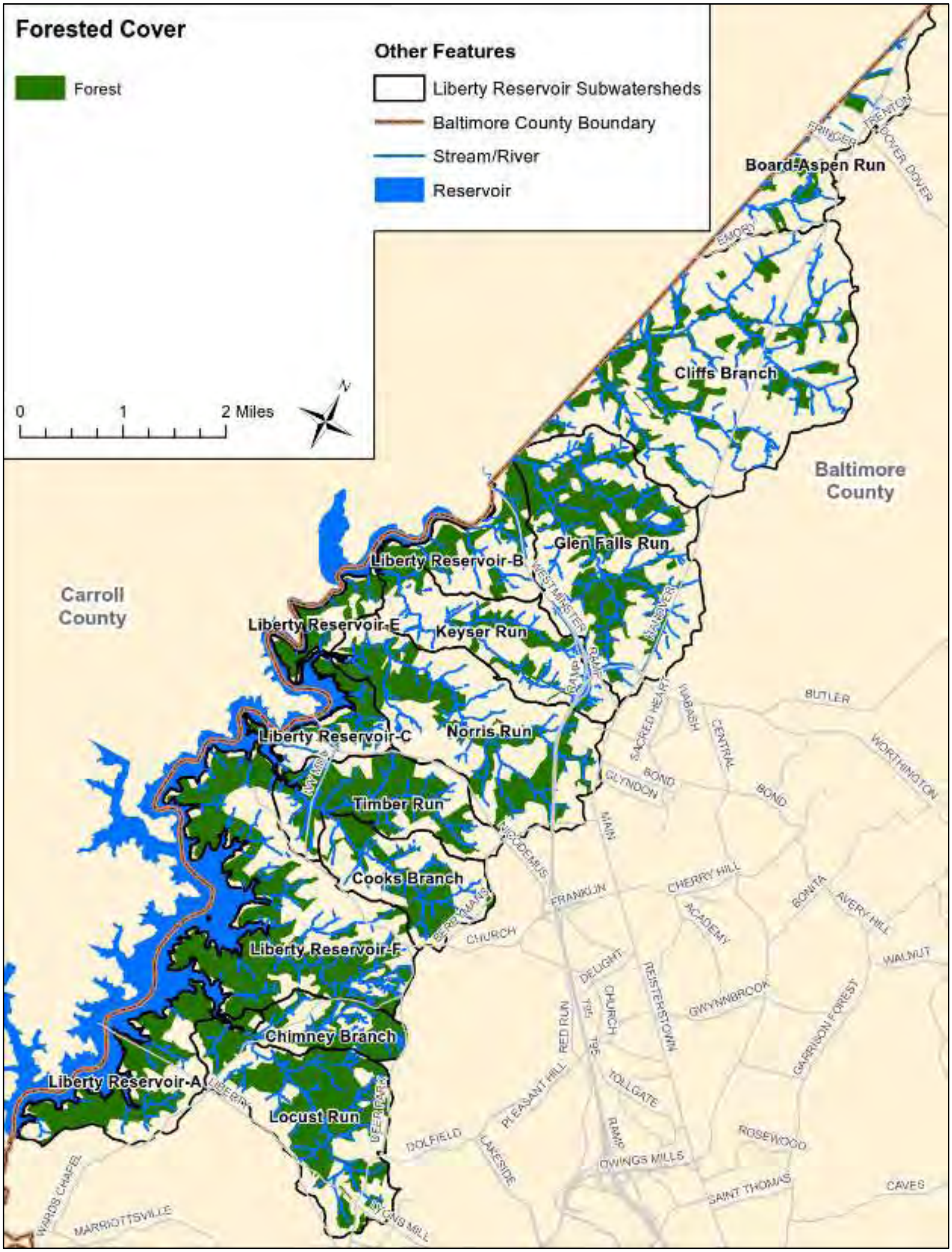

Figure 2-4: Liberty Reservoir Forest Cover

Table 2-5: Liberty Reservoir Acres of Forest Canopy per Land Use Classification

Subwatershed	Forest	Agriculture	Residential	Other	Total Forest Canopy	% Forest Canopy
Board-Aspen Run	92	62	75	2	231	30.5%
Cliffs Branch	597	210	248	34	1,089	34.7%
Glen Falls Run	851	72	312	51	1,286	62.4%
Liberty Reservoir-B	252	14	130	37	432	67.8%
Keyser Run	222	77	199	32	531	52.8%
Liberty Reservoir-E	149	17	4	19	190	67.9%
Norris Run	523	65	427	49	1,063	59.4%
Liberty Reservoir-C	185	68	45	33	331	84.7%
Timber Run	549	24	159	1	733	78.6%
Cooks Branch	301	13	235	0	549	69.9%
Liberty Reservoir-F	1,106	89	225	111	1,531	76.0%
Chimney Branch	236	20	46	2	305	69.4%
Liberty Reservoir-A	443	22	60	44	570	72.4%
Locust Run	781	48	159	27	1,015	71.1%
Total	***6,287***	***801***	***2,325***	***444***	***9,856***	***59.9%***

* includes tree canopy present on commercial, institutional, industrial, transportation, water/wetlands, and open urban land

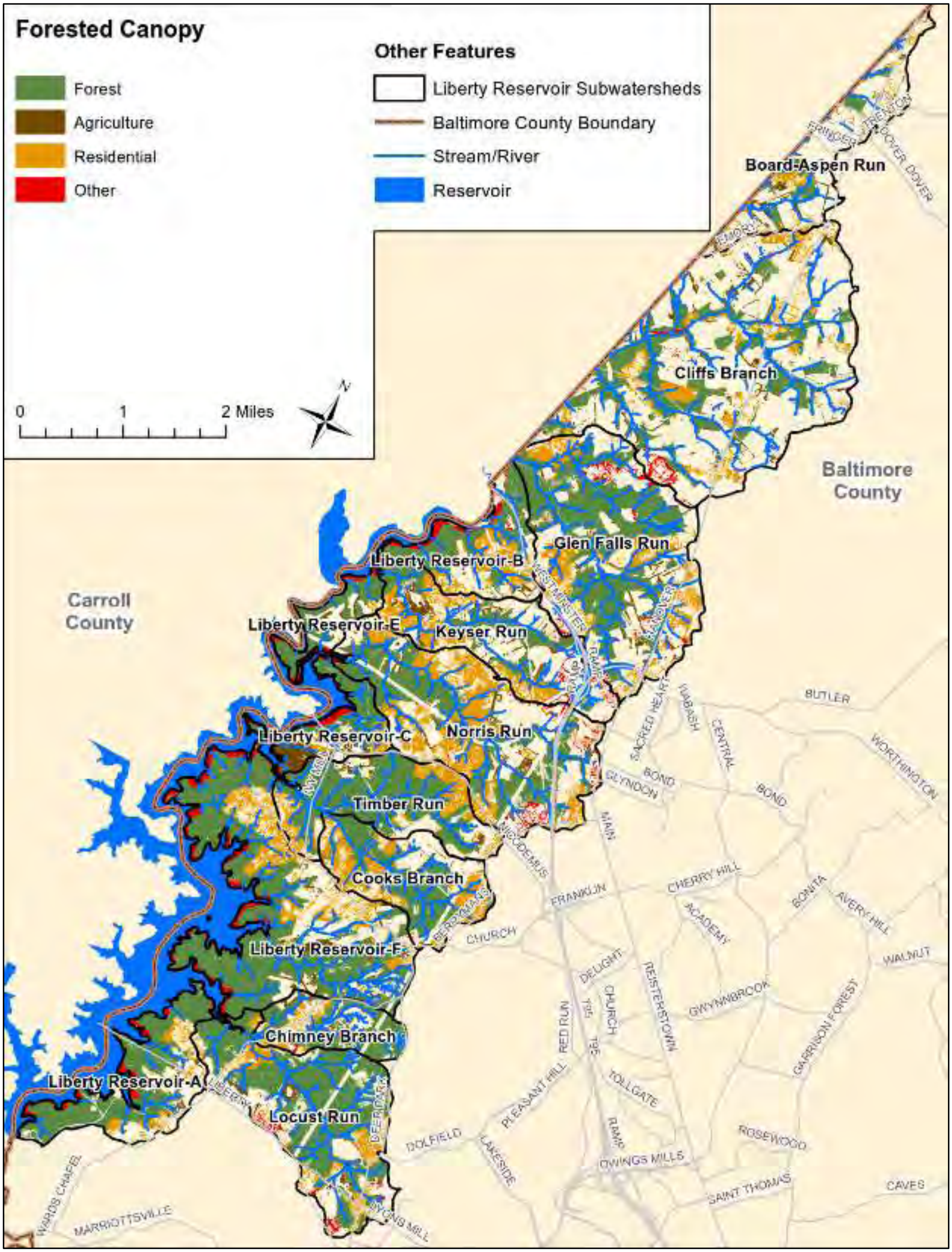

Figure 2-5: Liberty Reservoir Forest Canopy by Land Use Classification

2.2.7 Stream Systems

All of the streams within a watershed make up its stream system, the most visible part of the hydrologic cycle. Streams are the flowing surface waters of the watershed, and while they are separate from groundwater and standing surface water such as lakes, they are closely connected to both. The stream system is an intrinsic part of the landscape and closely reflects conditions on the land. Streams are a fundamental natural resource with numerous benefits for plants, animals, and humans. Maintaining a healthy stream system is a priority for many individuals and organizations and requires ensuring that stream flows and water quality closely mimic the conditions found in un-impacted watersheds.

2.2.7.1 Stream System Characteristics

The subwatersheds with the most stream miles include Cliffs Branch, Glen Falls Run, and Liberty Reservoir-F and compromise approximately 44% of all the stream miles in the watershed. The Liberty Reservoir watershed was divided into a smaller series of subwatersheds. These subwatersheds were delineated based on the drainage areas contributing to major creeks and rivers as well as geographic/property considerations within the watershed. Baltimore County delineated 14 subwatersheds for the Liberty Reservoir watershed. Figure 2-6 shows the system of streams and subwatersheds comprising the Liberty Reservoir watershed. Table 2-6 summarizes the number of stream miles in each subwatershed along with stream density, defined as miles of stream per square mile of subwatershed area. Comparing the stream density of each subwatershed gives an indication of how much the streams have been altered, especially headwater streams. Headwater streams are the smaller tributaries that carry water from the upper reaches of the watershed to the main channel. As an area becomes urbanized, headwater streams are often filled in or incorporated into storm sewer systems (i.e. piped). This alters the hydrologic connectivity and physical habitat of the headwater streams and consequently, the watershed as a whole. Comparing the stream densities of each subwatershed in Table 2-6 with the land uses in Table 2-8 shows a correlation between stream density and percent cover of forest, agriculture, and residential. Compared to the 13 completed SWAPs in Baltimore County that calculated stream density, Liberty Reservoir has one of the highest overall stream densities at 6.1 stream miles/sq. miles. Other watersheds have an average density between 0.9 and 7.0 steam miles/sq. miles, indicating that Liberty Reservoir has relatively unaltered stream channels.

There are nearly 158 miles of stream in the Liberty Reservoir watershed, all of which eventually drain to the Chesapeake Bay. Stream data for the watershed is provided by Baltimore County OIT based on the hydrology lines captured from 3D compilation processes using imagery captured in 2008.

Table 2-6: Liberty Reservoir Stream Mileage and Density

Subwatershed	Area (Sq Miles)	Stream Length (Miles)	Stream Density (mi. /sq. mi.)
Board-Aspen Run	1.18	5.25	4.43
Cliffs Branch	4.91	27.20	5.54
Glen Falls Run	3.22	24.46	7.60
Liberty Reservoir-B	1.00	5.32	5.34
Keyser Run	1.57	11.12	7.07
Liberty Reservoir-E	0.44	2.43	5.55
Norris Run	2.80	14.95	5.34
Liberty Reservoir-C	0.61	4.63	7.59
Timber Run	1.46	10.86	7.46
Cooks Branch	1.23	8.44	6.88
Liberty Reservoir-F	3.15	17.76	5.65
Chimney Branch	0.69	6.68	9.74
Liberty Reservoir-A	1.23	3.42	2.78
Locust Run	2.23	14.61	6.55
Total	***25.70***	***157.14***	***6.11***

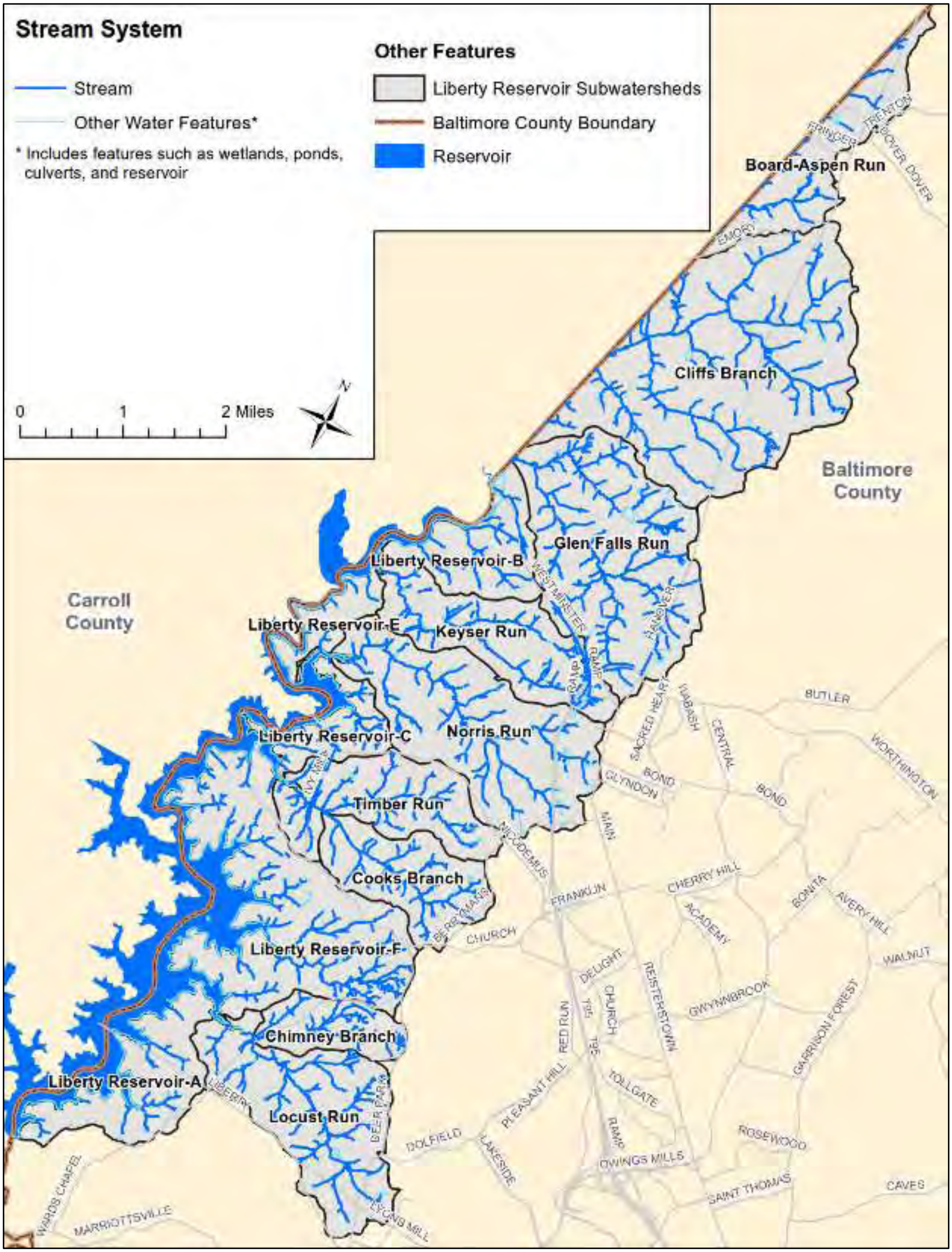

Figure 2-6: Liberty Reservoir Stream System

2.2.7.2 *Stream Riparian Buffers*

Riparian buffer refers to the vegetated area adjacent to streams and other water bodies that protect them from pollutant loads while also providing bank stabilization and habitat. Forested buffer areas along streams play a crucial role in improving water quality and flood mitigation as they can intercept and reduce surface runoff, stabilize stream banks, trap sediment, and provide habitat for various types of terrestrial and aquatic life. For example, tree roots capture and remove pollutants including excess nutrients such as nitrogen from shallow flowing water; the tree root structure also holds together the soil to reduce erosion potential and slows water flow which reduces sediment load and flooding risk. Tree canopies provide shade that helps to maintain the cooler water temperatures preferred by many aquatic organisms, particularly cold-water species like trout. In smaller tributaries, terrestrial plant material that falls into the stream is the primary source of food for stream life. While leaves provide seasonal food for stream life at the base of the food chain, fallen tree branches and trunks provide a more consistent, slow-release food source throughout the year. Tree roots and snags also offer habitat and spawning areas for fish and other aquatic species.

Maintaining healthy streams and forest buffers are important for reducing nutrient and sediment loads to the Liberty Reservoir watershed, and thus to the Chesapeake Bay. When stream riparian buffers are converted from forest to agriculture or urban development, many of these benefits are lost and stream health declines. Riparian buffer zones can be re-established or preserved as a BMP to reduce land use impacts by intercepting and controlling pollutants entering a water body.

The condition of stream riparian buffers in the Liberty Reservoir watershed was analyzed based on a 100-foot buffer on both sides of all streams. It should be noted that this 100-foot buffer is different than the regulated "forest buffer" mentioned in Article 33, Title 3 of the Baltimore County Code. The regulated forest buffer is used primarily as a setback when development is to occur near a stream. For this analysis, the condition of the riparian buffer was classified using three categories: impervious, open pervious, or forest. The stream data described in the previous section were used as a base to create the 100-foot buffer. The road and building data and the urban tree canopy data were overlaid with the 100-foot buffer area to obtain the impervious and forested areas lying within the buffer zone, respectively. Remaining areas that were not impervious or forested were classified as open pervious. Table 2-7 summarizes stream riparian buffer conditions by subwatershed and the spatial distribution is shown in Figure 2-7.

Table 2-7: Liberty Reservoir Land Cover in the 100-ft Stream Buffer

Subwatershed	IMPERVIOUS		OPEN PERVIOUS		FOREST		Total	Total % of
	Acres	%	Acres	%	Acres	%	Acres	Watershed
Board-Aspen Run	3.6	2.9%	56.7	45.6%	64.1	51.5%	124.5	3.2%
Cliffs Branch	9.5	1.5%	252.2	40.8%	356.4	57.7%	618.0	15.8%
Glen Falls Run	22.9	4.1%	97.5	17.4%	440.0	78.5%	560.5	14.3%
Liberty Reservoir-B	7.4	4.9%	38.2	25.6%	103.6	69.5%	149.2	3.8%
Keyser Run	15.1	5.8%	86.8	33.2%	159.6	61.0%	261.5	6.7%
Liberty Reservoir-E	0.3	0.4%	20.4	25.4%	59.6	74.2%	80.3	2.0%
Norris Run	8.8	2.4%	69.3	18.8%	290.4	78.8%	368.5	9.4%
Liberty Reservoir-C	2.6	2.0%	6.8	5.2%	121.5	92.8%	130.9	3.3%
Timber Run	3.2	1.4%	16.3	6.8%	219.1	91.8%	238.6	6.1%
Cooks Branch	0.7	0.4%	20.0	10.4%	171.5	89.2%	192.3	4.9%
Liberty Reservoir-F	5.8	1.0%	93.0	16.8%	453.7	82.1%	552.5	14.1%
Chimney Branch	0.9	0.6%	33.9	23.6%	109.3	75.9%	144.1	3.7%
Liberty Reservoir-A	1.5	1.0%	22.2	14.3%	131.5	84.7%	155.3	4.0%
Locust Run	2.8	0.8%	46.8	13.6%	293.5	85.5%	343.1	8.8%
Total	***85.2***	***2.2%***	***860.1***	***21.9%***	***2,973.9***	***75.9%***	***3,919.2***	***100.0%***

The largest percentage of the riparian buffers falls under forest (approximately 76%), which is an important area to protect and maintain. In comparison, total impervious areas within the stream riparian buffer zones are reasonably low at approximately 2% for the watershed, which is indicative of the rural setting of the watershed. Keyser Run has the highest subwatershed percentage of impervious area in the buffer zone at approximately 6% but consists of only 15.1 acres. Glen Falls Run has the largest overall area of impervious land in the buffer zone at approximately 23 acres, resulting in 4.1% of total buffer for the subwatershed. Though relatively low values, when compared with a more urban watershed, these areas may present potential opportunities for impervious cover removal or buffer establishment. The subwatershed with the highest open pervious acreage in the buffer zone is Cliffs Branch, 252 acres, and presents opportunities for potential reforestation efforts.

The subwatersheds with the most significant acreage of forested riparian buffer are Glen Falls Run and Liberty Reservoir-F with approximately 440 and 454 acres, respectively. These areas may present potential preservation opportunities. It is noteworthy that the majority of all subwatershed riparian buffers are forested. It appears that stream riparian buffers are relatively undisturbed or well maintained in these areas, which offers preservation and public education opportunities.

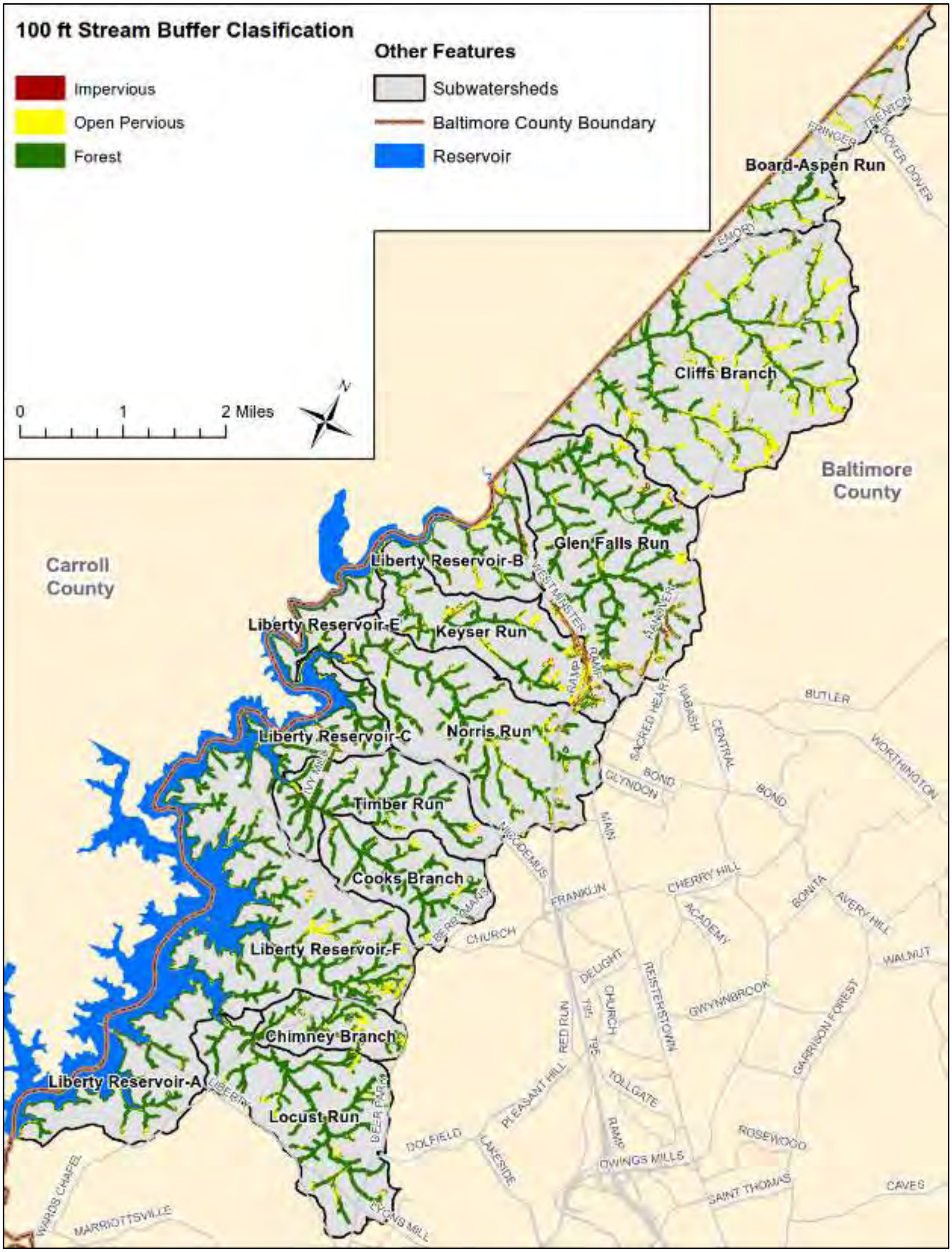

Figure 2-7: Liberty Reservoir 100-ft Stream Buffer Condition

2.2.7.3 Tier II High Quality Waters

The Clean Water Act requires regulations that set goals to protect each States' waters. Maryland's anti-degradation policy has been promulgated to provide implementation of more restrictive planning efforts in areas where Tier II (high quality) waters have been designated. This implementation has the greatest immediate effect on local government planning due to higher standards for discharge into Tier II waters (MDE, Maryland's High Quality Waters (Tier II), 2014b). Catchments that drain to Tier II waters are under regulatory anti-degradation protection that exceeds minimum applicable water quality criteria and standards. Currently, Tier II streams are identified according to fish and benthic indices of biotic integrity. Streams listed as Tier II waters will always remain Tier II waters.

The Liberty Reservoir watershed contains six stream segments classified as Tier II waters with two stream segments located in each the Glen Falls Run and Timber Run subwatersheds and one stream segment located in the Keyser Run and Cooks Branch subwatersheds. The two Tier II segments in Glen Falls Run are split between two Tier II catchments. The northern Tier II stream segment in the Glen Falls Run subwatershed and the stream segment in Cooks Branch are listed as having some assimilative capacity remaining; meaning the water body still has the natural capacity to dilute and absorb pollutants while remaining below water quality standards. The southern Tier II segment in the Glen Falls Run subwatershed and the segments in the Keyser Run and Timber Run subwatersheds are listed as having no assimilative capacity remaining, meaning that any future source of pollution (i.e., land development) must be treated by BMPs to prevent any further degradation of the high quality waters. Figure 2-8 shows the location of Tier II stream segments in the watershed as well as their corresponding catchment areas.

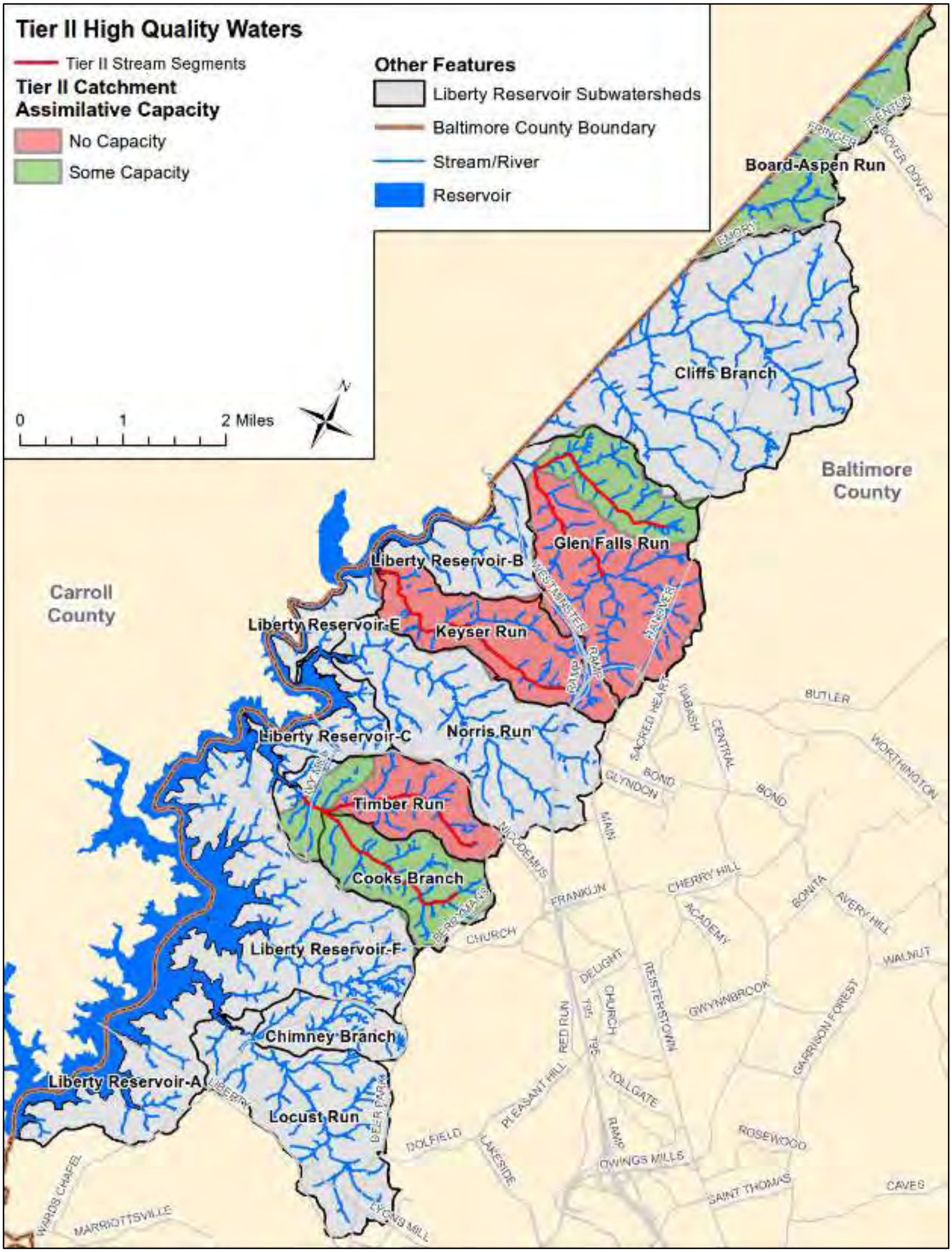

Figure 2-8: Tier II Waters within Liberty Reservoir

2.3 The Human Modified Landscape

Human activities have altered the natural landscape over time through the use of land and water resources. The intensity of development activities has increased since the colonization of Maryland in the 1600s, which has resulted in environmental impacts to both terrestrial and aquatic ecosystems. This section describes the characteristics of the human modified landscape and how it is associated with impacts to the natural ecosystem of the Liberty Reservoir watershed. This includes a description of land use and land cover, population, impervious cover, drinking water, wastewater, stormwater systems, discharge permits, and zoning.

2.3.1 Land Use and Land Cover

Land use represents the types of human activities taking place within a watershed and has pronounced impacts on water quality and habitat. The extent of these impacts, including types and amounts of pollutants generated, will vary depending on the land uses that are present in the watershed. As discussed previously, a forested watershed has the ability to absorb pollutants such as sediment and nutrients and to reduce the flow rate of runoff into streams. Developed areas have impervious surfaces that block the natural infiltration of precipitation into the ground. These impervious surfaces include roads, parking lots, roofs, and other human constructions. Unlike most natural surfaces, impervious surfaces tend to concentrate stormwater runoff, accelerate flow rates, and direct stormwater to the nearest stream. This behavior can cause bank erosion and destruction of in-stream and riparian habitat of the receiving water body and also prevent infiltration from occurring that would otherwise filter pollutants and recharge groundwater aquifers that help to maintain baseflow in a stream channel. For these reasons, undeveloped watersheds and those with smaller amounts of impervious surfaces tend to have better water quality in local streams than developed watersheds with larger amounts of impervious surfaces. In addition, agricultural land can contribute to increases in sediment, nutrients, pesticides/herbicides, and coliform bacteria in streams if not properly managed.

MDP develops statewide land use/land cover (LU/LC) spatial data to provide a general overview of predominant land cover and usage and to monitor development activities throughout the state. The LU/LC delineations are based on high altitude aerial photography and satellite imagery. In this report, land use analyses were performed using 2010 MDP land use spatial data provided by Baltimore County OIT. This data was originally based on the 2007 National Agriculture Imagery Program (NAIP) aerial imagery and parcel information from Maryland Property View 2008. Table 2-8 summarizes land use categories in the Liberty Reservoir watershed and their percent composition in each subwatershed. Figure 2-9 illustrates the LU/LC distribution in the watershed.

The predominant land use types present within the Liberty Reservoir watershed are forest and agriculture, making up approximately 42% and 25% of the total watershed area, respectively. Additionally, very low and low density residential, combined, cover approximately 7,919 acres or 24% of the total area. These four land use classifications equate to 91% of the total watershed area. The remaining 9% is divided between the remaining LU/LC classifications (commercial, industrial, bare ground, etc.), each covering less than 2.5% of the total watershed. Although a small percentage, these areas cover approximately 1,530 acres of the watershed. Additionally, institutional areas such as community centers, schools, churches, medical facilities, and government offices may present opportunities to initiate environmentally sensitive management of the property and provide opportunities for public outreach and education that promotes an increased level of environmental awareness.

The distribution of predominant land use type (very low and low density residential, agriculture, and forested) coverage varies between the subwatersheds within Liberty Reservoir. Timber Run and Chimney Branch contain the highest percentages of forest coverage at 62% and 66%, respectively. The subwatersheds with the highest percentages of residential areas include Norris Run and Cooks Branch at 38% and 46%, respectively. Residential areas present an opportunity for community involvement in restoration efforts, neighborhood pollutant source control, and environmental stewardship. Board-Aspen Run is primarily agricultural, with 56% agricultural land use/land cover. This area may indicate potential sources of sediment and nutrient loading into the stream system.

Table 2-8: Liberty Reservoir Land Use/Land Cover Classification (%)

Subwatershed	Agriculture - Cropland/Pasture/etc.	Very Low Density Residential	Low Density Residential	Medium Density Residential	High Density Residential	Industrial	Commercial	Institutional	Transportation	Open Urban Land	Brush	Deciduous/Evergreen/Mixed Forest	Water/Wetlands
Board-Aspen Run	55.9	10.5	13.5	2.6	0.0	0.0	1.5	0.9	0.0	0.3	0.0	14.9	0.0
Cliffs Branch	56.5	4.3	12.5	0.8	0.0	0.1	1.1	2.4	0.0	0.0	0.1	21.8	0.3
Glen Falls Run	16.2	10.3	16.5	2.1	0.0	0.0	3.3	5.5	0.9	0.0	0.8	44.0	0.4
Liberty Reservoir-B	9.7	10.2	23.8	0.0	0.0	0.0	0.7	0.8	2.0	0.0	0.0	42.0	10.8
Keyser Run	25.1	11.3	16.4	0.0	2.7	0.0	4.4	0.2	2.3	12.9	0.0	24.7	0.1
Liberty Reservoir-E	24.6	1.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.9	11.4
Norris Run	14.9	15.8	17.1	3.5	1.8	0.0	1.5	3.0	1.7	4.1	0.0	36.2	0.4
Liberty Reservoir-C	25.0	10.5	5.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	50.3	8.5
Timber Run	7.6	7.5	22.5	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	62.2	0.0
Cooks Branch	11.4	20.4	25.7	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0	42.1	0.0
Liberty Reservoir-F	14.6	9.5	11.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	58.1	6.5
Chimney Branch	13.0	8.3	12.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	65.5	0.0
Liberty Reservoir-A	13.5	5.8	11.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	59.2	6.4
Locust Run	9.3	6.3	12.1	2.3	0.0	0.0	4.6	0.3	0.0	2.9	1.7	60.2	0.3
Total % of SWAP Area	***24.5***	***9.3***	***14.8***	***1.1***	***0.4***	***0.0***	***1.6***	***1.6***	***0.5***	***1.5***	***0.4***	***42.1***	***2.1***

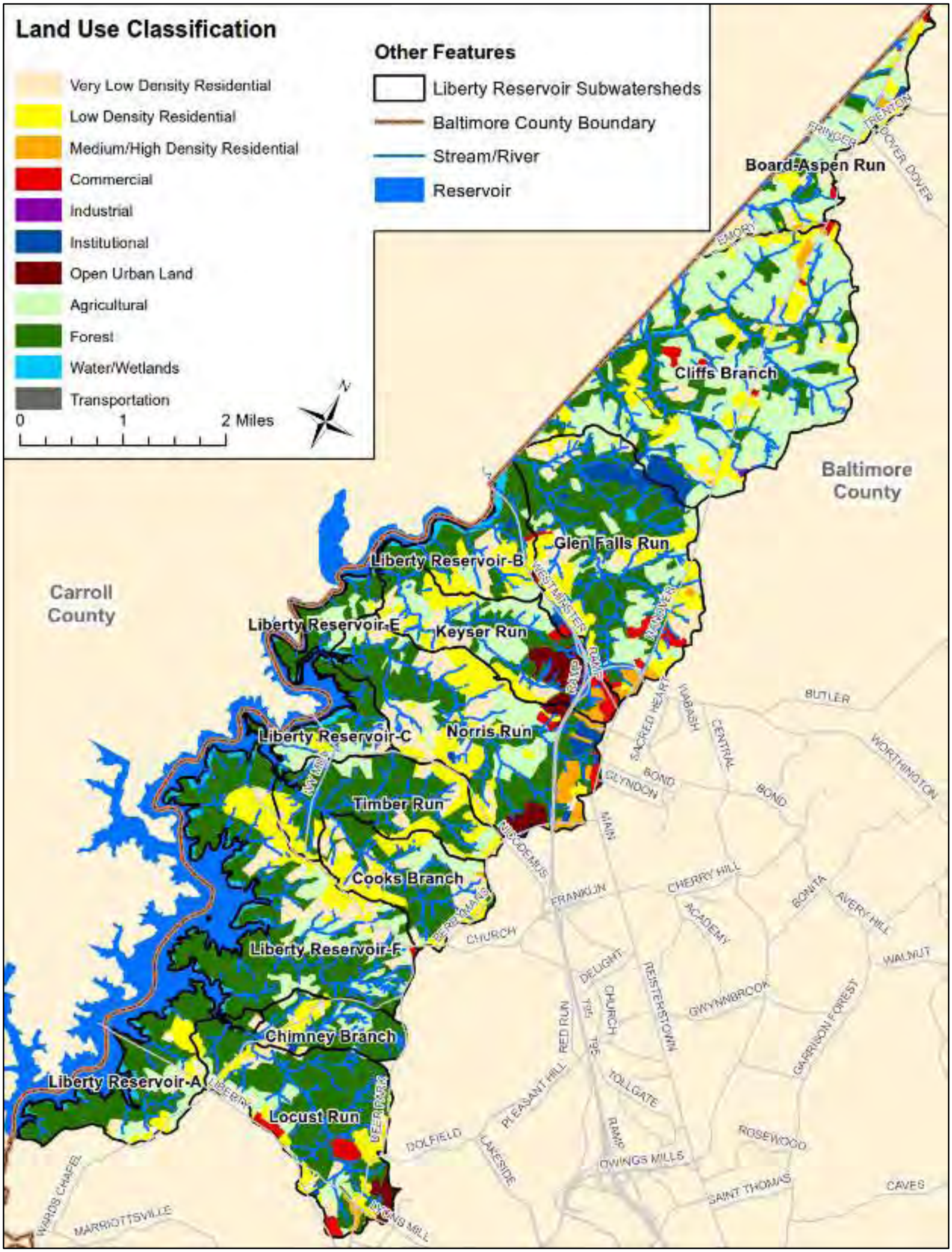

Figure 2-9: Liberty Reservoir Land Use/Land Cover

2.3.2 Population

Population data provides another method of evaluating the intensity of land use. Areas of concentrated population normally represent more intense use of the land and potential for environmental degradation. Much of the degradation from these locations (likely found in urban and suburban areas) is related to the extent of impervious cover and depletion of natural land covers such as forests that help to protect water resources. Smart growth principles are aimed at directing future growth to areas of existing services and locations where development has already begun. This strategy will result in less conversion into residential and commercial land uses, thereby promoting conservation of land uses with less environmental impact such as forest and agriculture.

Population data presented in this section are based on 2010 census blocks and population data from the U.S. Census Bureau. Table 2-9 summarizes population and population densities with respect to total area and total impervious area for each subwatershed. Higher amounts of impervious area per person could indicate potential sprawl development (such as larger homes), whereas the greater the population density per impervious acre could be more reflective of better clustering and smarter growth patterns. Figure 2-10 shows the distribution of population density throughout the Liberty Reservoir watershed. Because this watershed is rural and is predominantly very low/low density residential, population density is relatively low compared to most other watersheds in Baltimore County. The subwatershed with the highest population density is Keyser Run. The total population of the Liberty Reservoir watershed is 14,633 people with a population density of 0.89 people/acre.

Table 2-9: Liberty Reservoir Population Data

Subwatershed	Total Population (2010 census)	Total Area (Acres)	Population Density (per acre)	Impervious Area (Acres)	Impervious Acres per person	Population Density (per impervious acre)
Board-Aspen Run	438	758	0.58	49	0.11	9.02
Cliffs Branch	1,153	3,142	0.37	119	0.10	9.69
Glen Falls Run	1,954	2,059	0.95	117	0.06	16.66
Liberty Reservoir-B	637	638	1.00	33	0.05	19.18
Keyser Run	2,229	1,006	2.21	81	0.04	27.38
Liberty Reservoir-E	323	280	1.15	4	0.01	72.69
Norris Run	2,577	1,790	1.44	115	0.04	22.43
Liberty Reservoir-C	605	391	1.55	12	0.02	48.73
Timber Run	1,332	932	1.43	33	0.02	40.35
Cooks Branch	1,000	786	1.27	25	0.02	40.46
Liberty Reservoir-F	961	2,014	0.48	48	0.05	19.82
Chimney Branch	409	439	0.93	9	0.02	44.57
Liberty Reservoir-A	125	786	0.16	19	0.15	6.58
Locust Run	889	1,428	0.62	43	0.05	20.58
Liberty Reservoir Total	***14,633***	***16,449***	***0.89***	***709***	***0.05***	***20.6***

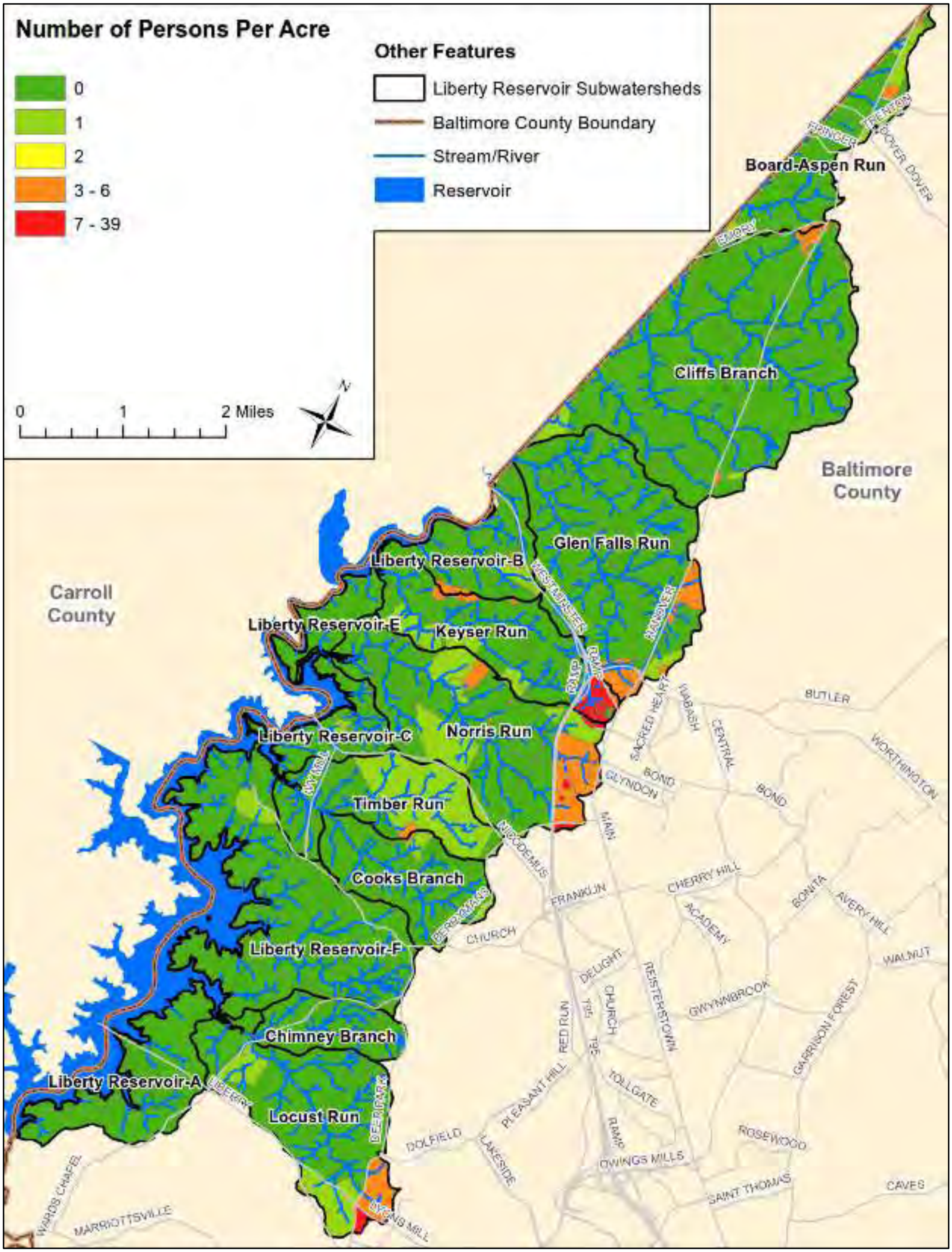

Figure 2-10: Liberty Reservoir Population Distribution

2.3.3 Impervious Surfaces

Impervious surfaces such as roads, parking lots, roofs, and other paved areas prevent precipitation from naturally infiltrating into the ground. Stormwater runoff from these areas becomes overland flow and is typically concentrated, accelerated, and conveyed directly to the nearest stream. Consequently, the high energy flows of stormwater runoff from impervious surfaces can cause stream erosion and habitat destruction. This runoff is also likely to be more polluted than runoff from pervious areas. In general, undeveloped watersheds with small amounts of impervious cover are more likely to have better water quality in local streams than urbanized watersheds with greater amounts of impervious cover.

Impervious cover is a primary factor when determining pollutant characteristics and quantities in stormwater runoff. Research has been conducted to link the degree of urbanization (typically measured by amount of impervious cover) with various watershed-based indicators of water quality such as diversity and abundance of aquatic and terrestrial life. The Center for Watershed Protection (CWP) compiled stream research conducted in various parts of the country and developed a simple model that relates potential stream quality to percentage of impervious cover in a watershed. Studies used to develop the impervious cover model measured stream quality based on a variety of indicators such as number of aquatic insect species, stream temperature, channel stability, aquatic habitat, wetland plant diversity, and fish communities present.

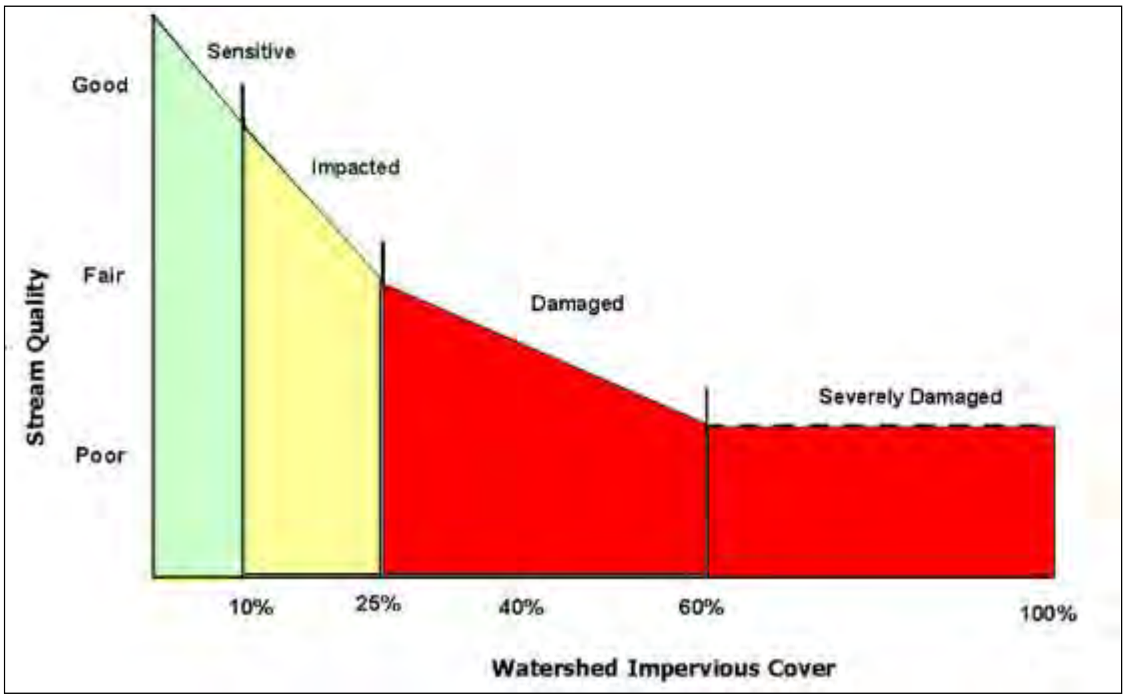

Figure 2-11: Impervious Cover Model (adapted from (CWP, 2003))

Based on the compiled research, CWP determined four classifications that predict stream quality based on watershed imperviousness: sensitive; impacted; damaged; or severely damaged. Watersheds with less than 10 percent impervious cover are referred to as sensitive and typically have high quality streams with stable channels, good habitat conditions, and good to high water quality. These watersheds are considered sensitive because they are susceptible to environmental degradation with increased urbanization and impervious cover. The model predicts that with between 10 and 25 percent impervious cover, watersheds become impacted and show clear signs of degradation such as erosion, channel widening, and a decline in stream habitat. There is potential to restore streams to a somewhat natural functioning system within this category. When a watershed has more than 25 percent impervious cover, streams are classified as damaged and characterized by fair to poor water quality, unstable channels, severe erosion, and inability to support aquatic life and provide habitat; many streams in this category are typically piped or channelized, or in some areas, may be piped beneath the impervious surfaces resulting in a lack of continuity between natural riparian areas along the stream corridor.

Figure 2-11 shows that when impervious cover exceeds 60 percent, a watershed is classified as severely damaged which means that most of the natural stream system has diminished. Management of damaged and severely damaged streams may focus on decreasing pollutant loads to downstream receiving waters (e.g., installing Best Management Practices (BMPs)) but the ability to restore natural functions, such as habitat, is unlikely. Restoration efforts may also focus on making the remaining stream systems stable, aesthetically pleasing, and an amenity to the community. It should be noted that the impervious cover model is a simplified approach for classifying the potential stream quality. Although it is based on research, there are inherent model assumptions and limitations that should be considered such as regional variations and scale effects. In addition, while impervious cover is a relevant and significant indicator for watershed health, it is only one of many different factors affecting stream health and contributing to the cumulative impacts of development on water quality. For example, agricultural land uses may also contribute sediment and nutrient loads to receiving waters. Furthermore, the ability of BMPs to offset adverse impacts from urbanized areas is not specifically accounted for in the model (CWP, 2003).

Impervious cover data for the Liberty Reservoir watershed was obtained from 2008 road and 2005 building spatial data provided by Baltimore County OIT. Impervious area quantities shown in Table 2-10 are the sum of road and building areas. The table also shows the percentage of impervious cover within each subwatershed. It should be noted that parking lots are included in the roads column of Table 2-10, whereas sidewalks are not included. Figure 2-12 illustrates the location of impervious surfaces within the Liberty Reservoir watershed. The total impervious area calculated is approximately 710 acres or 4.3% of the watershed. Subwatersheds with the highest percentage of impervious cover include Board-Aspen Run, Keyser Run, and Norris Run, although none of them reach the 10% threshold.

Table 2-10: Liberty Reservoir Impervious Area Estimates

Subwatershed	Total Area (Acres)	Roads (Acres)	Buildings (Acres)	Impervious Area (Acres)	% Impervious	CWP Impervious Rating
Board-Aspen Run	758	37	11	49	6.4%	Sensitive
Cliffs Branch	3,142	86	33	119	3.8%	Sensitive
Glen Falls Run	2,059	87	30	117	5.7%	Sensitive
Liberty Reservoir-B	638	27	6	33	5.2%	Sensitive
Keyser Run	1,006	61	20	81	8.1%	Sensitive
Liberty Reservoir-E	280	4	1	4	1.6%	Sensitive
Norris Run	1,790	82	33	115	6.4%	Sensitive
Liberty Reservoir-C	391	10	2	12	3.2%	Sensitive
Timber Run	932	24	9	33	3.5%	Sensitive
Cooks Branch	786	16	8	25	3.1%	Sensitive
Liberty Reservoir-F	2,014	36	13	48	2.4%	Sensitive
Chimney Branch	439	7	2	9	2.1%	Sensitive
Liberty Reservoir-A	786	13	6	19	2.4%	Sensitive
Locust Run	1,428	26	17	43	3.0%	Sensitive
Total	***16,449***	***517***	***192***	***709***	***4.3%***	***Sensitive***

Based on the CWP model (Figure 2-11), all of the subwatersheds within the Liberty Reservoir watershed fall into the sensitive impervious rating. Because this watershed drains directly into a drinking water reservoir, the quality of water necessary is high and must be preserved. In addition to impervious cover, other key watershed indicators must be examined to determine watershed health and restoration potential.

Figure 2-13 shows the impervious cover ratings for the subwatersheds in the Liberty Reservoir watershed based on the reformulated impervious cover model. As expected from the rural nature of the watershed and high percentages of forest and agricultural land use, the Liberty Reservoir watershed does not contain any impacted, damaged, or severely damaged subwatersheds. “Impacted” subwatersheds mainly correspond to those with high amounts of residential development, “damaged” subwatersheds have more commercial development associated with more impervious cover density, and “severely damaged” is correlated with vast development completely altering the natural system. These categories are associated with urbanization and high impervious cover, both of which are not prominent characteristics of the Liberty Reservoir watershed. Sensitive watersheds are susceptible to impacts from development and need to be protected and conserved to prevent future degradation. This is especially true for the subwatersheds within the transitional band from 5 to 10% impervious cover. Three different ranges of imperviousness are depicted in Figure 2-13 to indicate those watersheds that are reaching the 10% threshold.

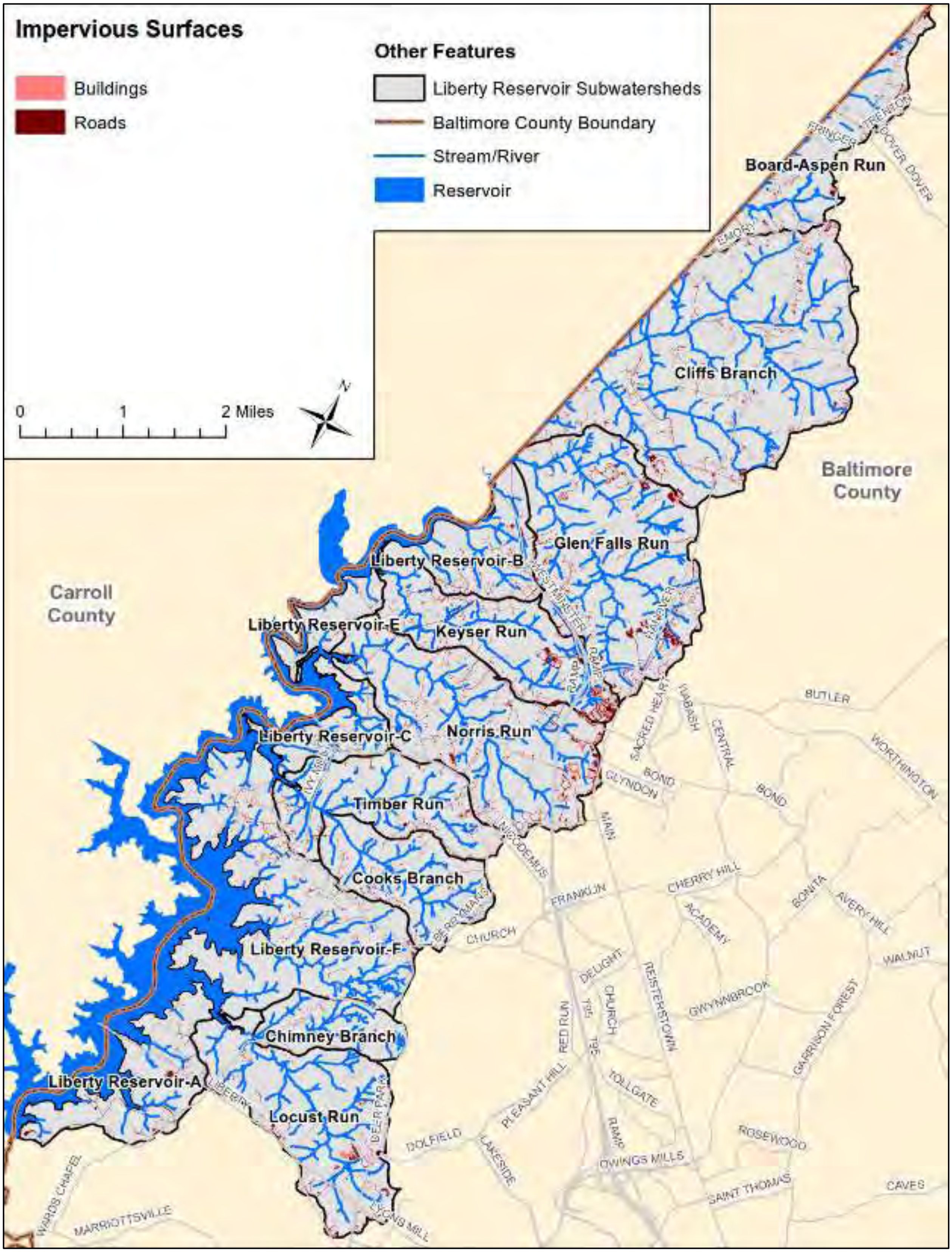

Figure 2-12: Liberty Reservoir Impervious Surfaces

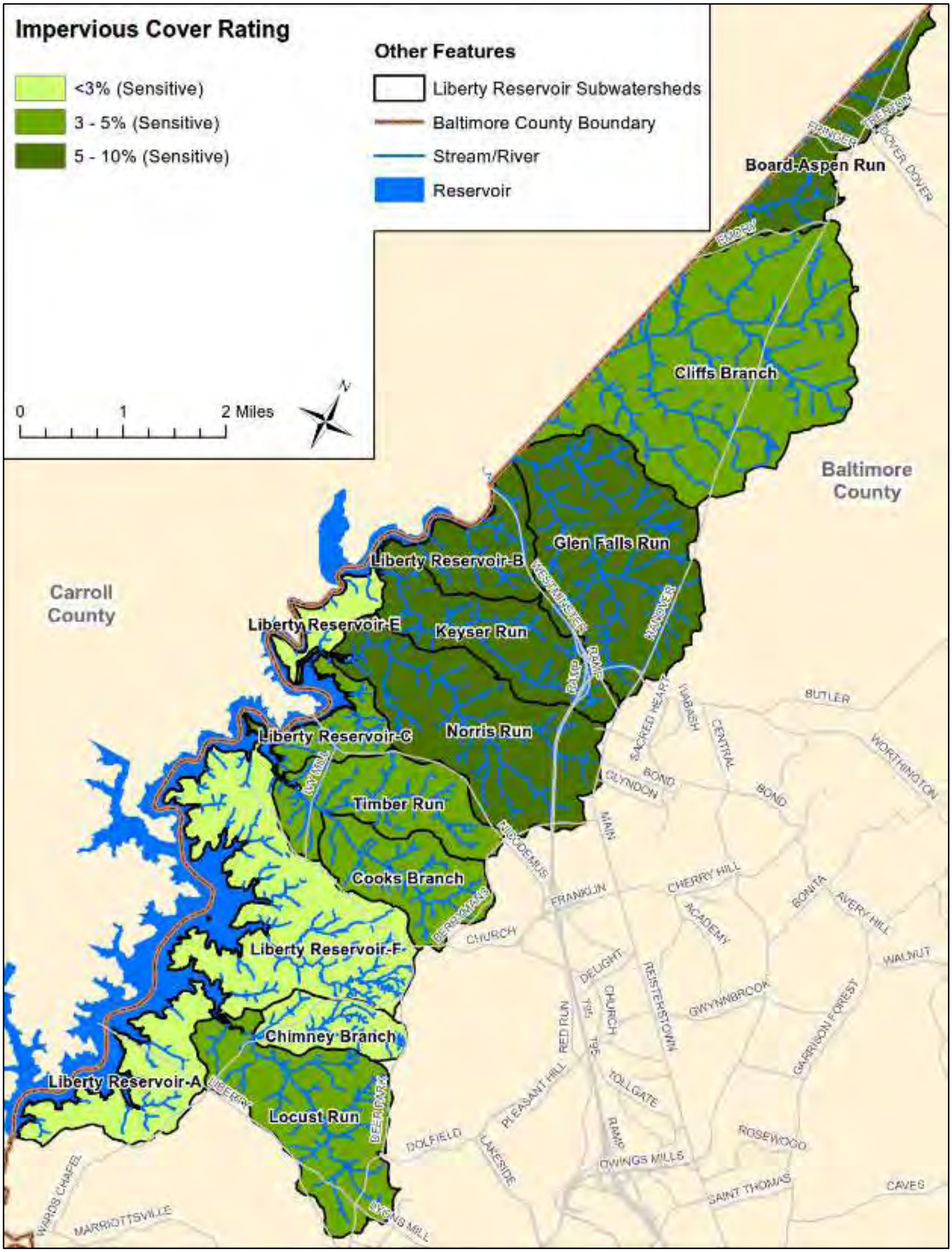

Figure 2-13: Liberty Reservoir Impervious Cover Ratings

2.3.4 Urban/Rural Demarcation Line

The majority of the Liberty Reservoir watershed lies outside of the Urban/Rural Demarcation Line (URDL) growth boundary. Table 2-11 summarizes the subwatershed areas located within the urban section of the URDL. Figure 2-14 shows the URDL boundary and the portions of the Liberty Reservoir watershed that fall within the URDL. No public water or sewer services are offered to areas outside of the boundary. The URDL was established by the Baltimore County Planning Board in 1967 to limit growth and preserve natural and agricultural resources. Of the 14 subwatersheds within the Liberty Reservoir watershed, only Keyser Run, Glen Falls Run, Norris Run, Locust Run, and Cooks Branch subwatersheds lie partially within the URDL growth boundary.

Table 2-11: Area of Watershed within Urban Rural Demarcation Line

	Area of Watershed within Urban Rural Demarcation Line		
Subwatershed	Area within URDL (Acres)	Area of Subwatershed (Acres)	% within URDL
Glen Falls Run	66	2,059	3.2
Keyser Run	86	1,006	8.5
Norris Run	260	1,790	14.5
Cooks Branch	4	786	0.5
Locust Run	47	1,428	3.3
Total Liberty Reservoir Watershed	***463***	***7,070***	***6.6***

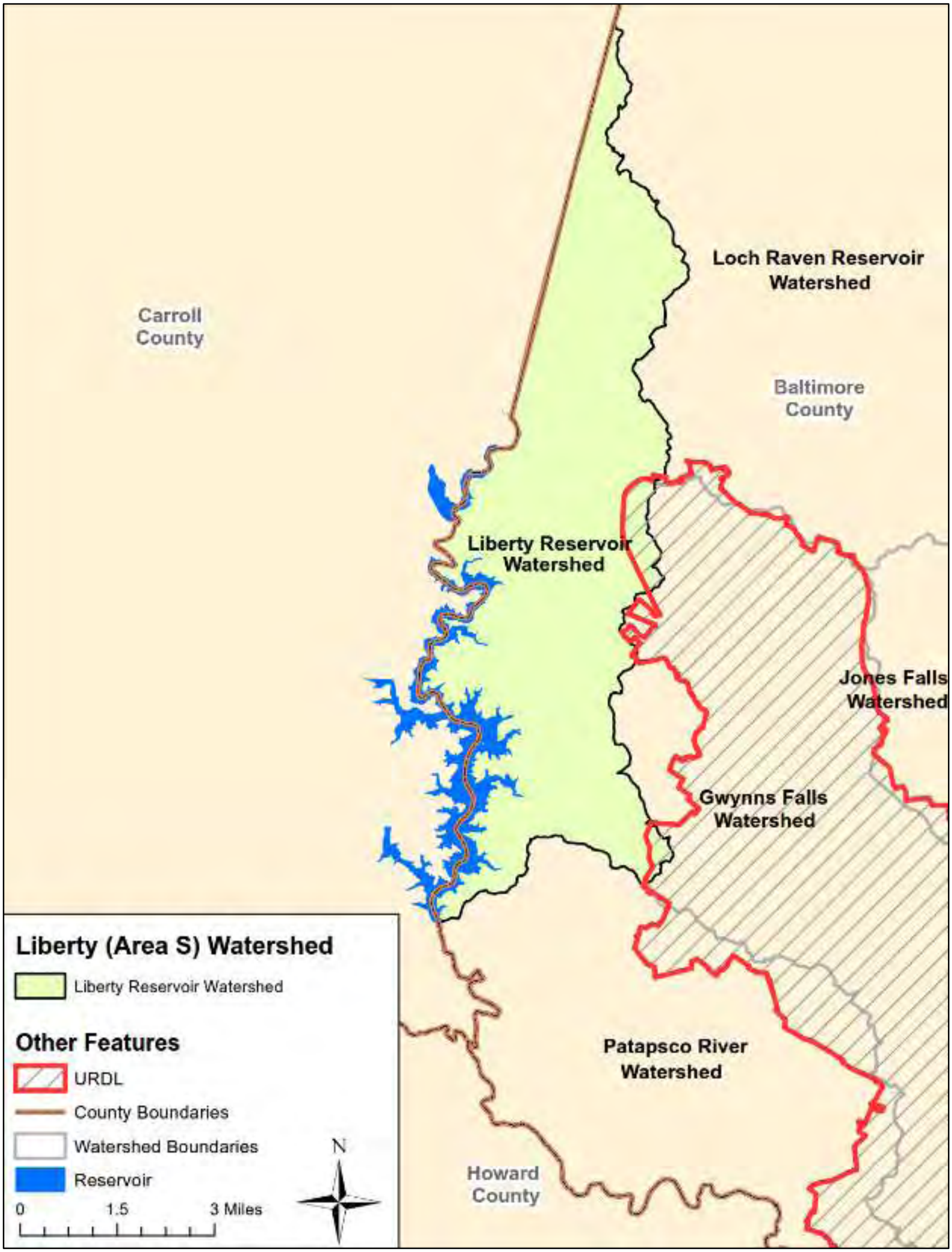

Figure 2-14: Liberty Reservoir and the Urban Rural Demarcation Line growth boundary

2.3.5 Drinking Water

Drinking water is a fundamental need for human development. It can be supplied either by public distribution systems or by wells associated with individual developed properties. Having an adequate supply of drinking water and a method for its conveyance is essential to the human population.

2.3.5.1 Public Water Supply

Environmental impacts associated with the public supply of water include the potential for increased residential development with the associated effects of increased impervious cover as discussed in the previous section, as well as the potential for leaks from the system. Leaks from public water supply systems introduce chlorine into the aquatic system which can result in the death of aquatic organisms. In addition, major leaks can cause erosion which contributes to the sediment load in the stream channels; this can bury aquatic communities and degrade habitat. As most of the Liberty Reservoir watershed is located outside the URDL, there is no public water supply for the majority of the residents and most rely on well water to meet their drinking water needs. However, the entire watershed drains to the reservoir, which supplies drinking water to 1.8 million residents in Carroll County, Baltimore County, and Baltimore City. The reservoir is owned and managed by Baltimore City (BMC, 2009).

The Liberty Reservoir watershed within Baltimore County encompasses approximately 16% of the reservoir's total drainage area. Therefore, the activities and land uses in the Liberty Reservoir watershed have a direct impact on the quality of water in the reservoir. The reservoir impoundment and the majority of its tributaries within the watershed are designated as *water contact recreation, protection of aquatic life, and public water supply.* The remaining subwatersheds and their tributaries, Norris Run, Cooks Run, Keysers Run, Locust Run, and Glen Falls Run, are designated as *nontidal cold water and public water supply* (COMAR, 2014a). These designated uses will be discussed further in Chapter 3.

2.3.5.2 Private Well Supply

The residents and businesses in the Liberty Reservoir watershed rely on private wells to supply their drinking water needs. The well water quality and quantity is affected by the region's crystalline-rock formations. The aquifers in the Piedmont portion of Baltimore County are susceptible to groundwater contamination because they lack a confining layer, and ground water contamination is generally caused by land use activities in the immediate vicinity of the well (Bolton, 1998). Historically, the overall quality of well water in the study area was found to be within drinking water standards, with limited elevated concentrations of nitrates, lead, pesticides, and chloride, although these concentrations rarely exceeded water quality standards (Bolton, 1998). Naturally occurring radionuclides have been detected in areas with Baltimore and Setters Gneiss, and it is recommended that homeowners get their water tested for radium and treated if necessary (EPS, 2011).

2.3.6 Wastewater

Wastewater produced by human processes must be treated and disposed of properly. This is accomplished through public conveyance to a treatment facility or through on-site disposal systems such as septic systems. Residential wastewater consists of all water typically used by residents including wash water, bathroom water, and any other rinse water such as paint brush, floor washing, etc. Industrial wastewater can contain various contaminants such as metals, organic compounds, detergents, or synthetic compounds depending on the operation. All of these wastewater types have the potential to adversely impact the natural environment.

2.3.6.1 Public Sewer

The public sewer system conveys wastewater from individual households or businesses to a facility that treats the wastewater prior to discharge. It consists of the piping system within the public right-of-way and cleanouts on individual properties. Property owners are responsible for the maintenance of their individual cleanouts. The portion of the system within the public right-of-way is owned and maintained by the local government, including the gravity piping system, access manholes, pumping stations, and force mains. Table 2-12 below summarizes the lengths of public sewer piping in the Liberty Reservoir watershed by type (gravity main or pressurized main). This data was compiled from gravity main, manhole, and force main spatial data provided by Baltimore County OIT. Any abandoned gravity main pipes were subtracted from the total length of public sewer piping. Table 2-13 summarizes public sewer piping density (length of sewer main per square mile of subwatershed area). While the majority of the Liberty Reservoir watershed lies outside of the URDL growth boundary, small portions of Glen Falls Run, Keyser Run, Norris Run, and Locust Run subwatersheds contain public sewer systems and are being reported. The sewer systems are located at the eastern point of the subwatersheds. The remaining 10 subwatersheds contain no reported public sewer piping.

Table 2-12: Public Sewer Piping Length in Liberty Reservoir Watershed

Subwatershed	Pressurized Main (ft.)	Gravity Main (ft.)	Gravity Main Abandoned (ft.)	Total Maintained (ft.)
Glen Falls Run	0	1,380	0	1,380
Keyser Run	0	8,130	421	7,709
Norris Run	0	9,207	0	9,207
Cooks Branch	0	0	0	0
Locust Run	0	1,963	0	1,963
Total	0	20,680	421	20,259

Table 2-13: Public Sewer Piping Density in Liberty Reservoir Watershed

Subwatershed	URDL Area (sq. Miles)	Pressurized Main (ft./sq. mi)	Maintained Gravity Main (ft./sq. mi)
Glen Falls Run	0.13	0	10,303
Keyser Run	0.07	0	103,973
Norris Run	0.01	0	1,411,739
Cooks Branch	0.41	0	0
Locust Run	0.10	0	18,984

Environmental impacts associated with the public sewers are usually the result of sewage overflows. Sanitary sewer overflows (SSOs) typically result from blockages in the sewage system, pumping station failure, or rainwater inflows exceeding pipe capacity. Contamination can also occur during dry weather due to leaks in the sewer system. Water quality concerns related to sewer overflows and leaks include high bacteria concentrations, release of nutrients, increased turbidity (cloudiness), and low dissolved oxygen concentrations. Two SSOs have been recorded in the Liberty Reservoir watershed due to blockages in the sewer system. Both recorded SSOs occurred in 2004 within the Keyser Run subwatershed. The documented SSOs will be discussed in more detail in Chapter 3.

2.3.6.2 Wastewater Treatment Facilities

There are no wastewater treatment facilities located in the Liberty Reservoir watershed. The wastewater from the Liberty Reservoir watershed that is conveyed through public sewers is sent to the Patapsco Wastewater Treatment Plant.

2.3.6.3 Septic Systems

Properly functioning septic systems provide treatment for nearly all the phosphorus present in wastewater but these systems can leak nitrogen in the form of nitrates into the groundwater. Depending on the location of the system, nitrates may be reduced or eliminated through de-nitrification as the treated water passes through riparian buffers, with forested buffers having a higher level of treatment over grassy buffers. Failing systems can release nitrogen, phosphorus, and other chemicals, contaminating the downstream aquatic environment. They can also result in increased bacterial contamination of nearby streams and therefore increase potential human health concerns. Table 2-14 summarizes the approximate number of septic systems present in the Liberty Reservoir watershed by subwatershed. Septic system data is based on the 2011 septic and public sewer spatial data from Baltimore County Environmental Protection and sustainability (EPS). Based on this data, the Cliffs Branch subwatershed contains the most septic systems of all subwatersheds, over 85% of which are residential. Figure 2-15 shows the distribution of residential and non-residential septic systems throughout the Liberty Reservoir watershed.

Table 2-14: Liberty Reservoir Septic Systems by Subwatershed

Subwatershed	Residential	Non-Residential	Total # of Septic Systems
Board-Aspen Run	132	11	143
Cliffs Branch	339	58	397
Glen Falls Run	272	58	330
Liberty Reservoir-B	70	3	73
Keyser Run	146	20	166
Liberty Reservoir-E	6	0	6
Norris Run	326	8	334
Liberty Reservoir-C	29	3	32
Timber Run	144	2	146
Cooks Branch	149	2	151
Liberty Reservoir-F	147	21	168
Chimney Branch	27	2	29
Liberty Reservoir-A	55	10	65
Locust Run	186	60	246
Total	***2,028***	***258***	***2,286***

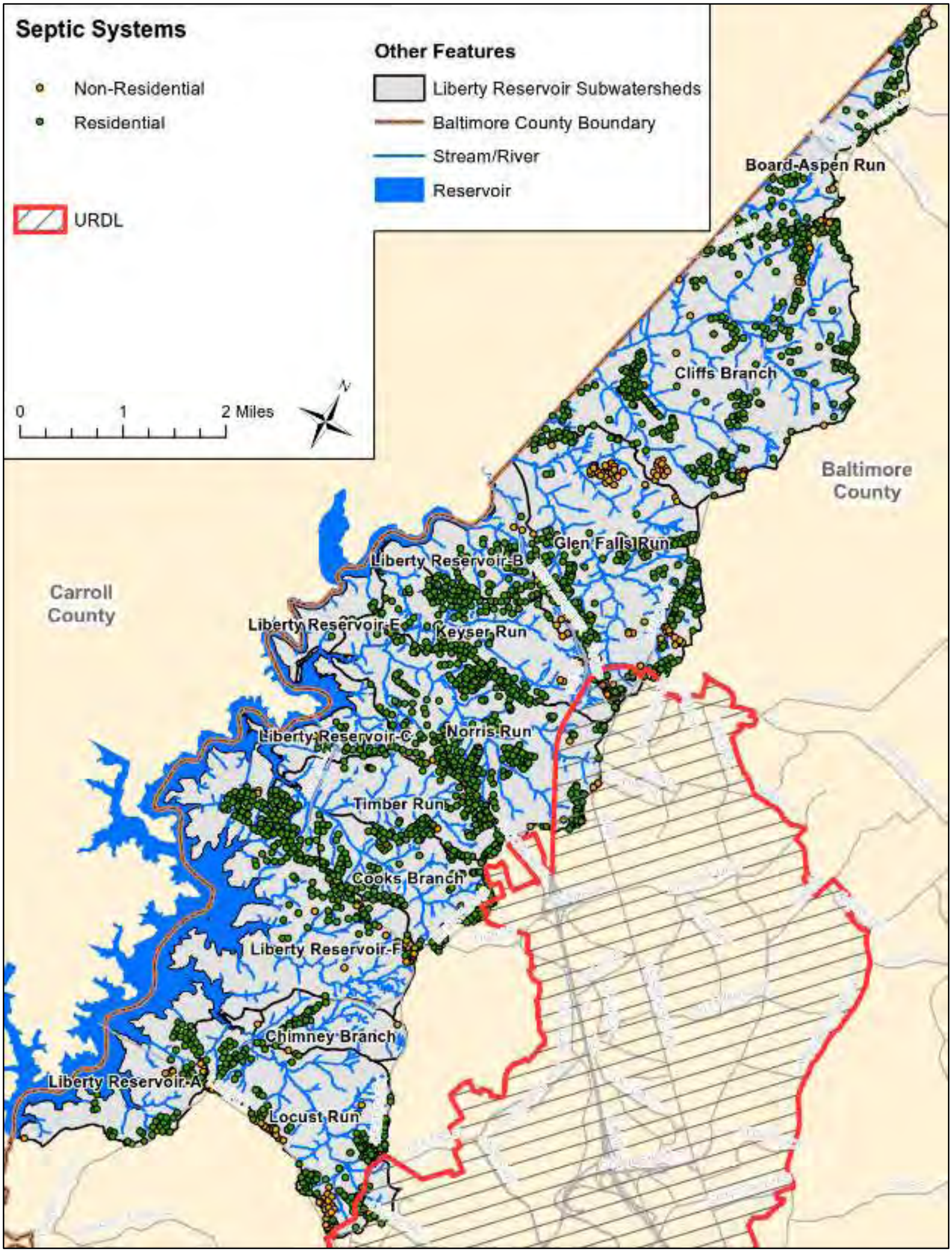

Figure 2-15: Location of Septic Systems in Liberty Reservoir Watershed

2.3.7 Stormwater

Stormwater is generated during and immediately after storm events. Precipitation that does not seep into the ground becomes stormwater runoff and flows directly to storm drain systems, stormwater treatment facilities, or receiving water bodies. The quantity and characteristics of stormwater runoff are affected by the quantity and intensity of rainfall, soil properties, land slope, and land use/land cover type. Concerns associated with stormwater include 1) volume and rate of runoff and 2) water pollution.

As previously discussed, larger volumes of stormwater runoff are generated from impervious areas than from undeveloped land; impervious surfaces prevent infiltration of runoff into the ground, conveying it to stream systems more swiftly and in larger quantities. The increase in runoff rate and volume can cause flooding and stream erosion, which results in destruction of habitat and natural stream functions such as nutrient reduction. In addition, there is less potential for groundwater recharge when there is little or no infiltration of stormwater.

Stormwater runoff can contain various contaminants depending on the land use characteristics and human activities that are taking place within a watershed. The contaminants that are carried by stormwater to the stream systems include pollutants deposited on impervious surfaces and other developed lands from daily human activity. Common pollutants found in impervious surface runoff (such as from highways and parking lots) are sediment, metals, bacteria, nutrients, petroleum, salt, and litter. These pollutants accumulate over time from sources such as road maintenance activities (de-icing), vehicles (exhaust and leaks), and accidents or spills and are washed off during storm events. While the runoff from other developed lands, for example agriculture and residential areas, may be moderate compared to highly impervious areas, it can still carry pollutants such as nutrients, bacteria, and chemicals to receiving water bodies. In addition, stormwater transports pollutants introduced by atmospheric deposition, most notably nitrogen and mercury, into receiving water bodies.

2.3.7.1 Storm Drainage System

The storm drainage system consists of either drainage swales (roadside ditches) or a curb and gutter system including inlets, piping, and outfalls. Both conveyance methods are intended to prevent flooding and potentially hazardous situations by removing water quickly from roadways. However, the efficiency and watershed impacts associated with each method differ significantly. The curb and gutter system drains stormwater more rapidly from impervious surfaces than drainage swales and typically convey water directly into the stream system. In doing so, however, it conveys increased runoff volumes and more untreated pollutants to receiving water bodies. Currently, Baltimore County's storm drainage system is comprised of approximately 1,760 miles of storm drain pipe, over 72,000 inlet structures, and over 41,000 storm manhole structures.

Drainage swales typically convey stormwater at a slower velocity than the curb and gutter system, and also allow some infiltration into the ground unlike the curb and gutter system, thereby reducing the amount of water delivered to the streams and providing some filtering of pollutants.

Table 2-15 summarizes the curb and gutter system components in the Liberty Reservoir watershed by subwatershed. The summary includes estimates of major outfalls (greater than 3 feet in diameter) and minor outfalls (less than 3 feet in diameter), along with corresponding number of inlets and pipe length draining to those outfalls. Storm drain system data used to compile this information was created by Baltimore County EPS based on stormdrain plans and topographic data. This data provides a reasonable approximation of storm drain pipe lengths.

Table 2-16 provides a summary of the percentage of each subwatershed that is covered by the storm drain system, identified as the drainage areas of the storm drain system, divided by the total subwatershed area. It also shows the inlet density (number of inlets per square mile) of each subwatershed.

Table 2-15: Stormwater System Components in Liberty Reservoir Watershed

	MAJOR (> 3ft)			MINOR (< 3ft)			ALL OUTFALLS		
Subwatershed	Outfalls (#)	Inlets (#)	Pipe (ft.)	Outfalls (#)	Inlets (#)	Pipe (ft.)	Total Outfalls (#)	Total Inlets (#)	Total Piping (ft.)
Board-Aspen Run	0	0	0	1	4	530	1	4	530
Cliffs Branch	0	0	0	2	4	915	2	4	915
Glen Falls Run	0	0	0	8	24	3,464	8	24	3,464
Liberty Reservoir-B	0	0	0	2	3	130	2	3	130
Keyser Run	0	0	0	3	6	845	3	6	845
Liberty Reservoir-E	0	0	0	0	0	0	0	0	0
Norris Run	1	17	2,059	4	7	1,830	5	24	3,889
Liberty Reservoir-C	0	0	0	0	0	0	0	0	0
Timber Run	0	0	0	2	6	1,295	2	6	1,295
Cooks Branch	0	0	0	3	9	1,120	3	9	1,120
Liberty Reservoir-F	0	0	0	2	8	1,200	2	8	1,200
Chimney Branch	0	0	0	0	0	0	0	0	0
Liberty Reservoir-A	0	0	0	3	5	395	3	5	395
Locust Run	0	0	0	0	0	0	0	0	0
Total	***1***	***17***	***2,059***	***30***	***76***	***11,724***	***31***	***93***	***13,783***

Table 2-16: Stormwater System Coverage in Liberty Reservoir Watershed

Subwatershed	Subwatershed Area (Acres)	Stormwater System Drainage Area* (Acres)	Area Covered by Stormwater System (%)	No. of Inlets (#)	Subwatershed Area (sq. mi)	Inlet Density (#/sq. mi)
Board-Aspen Run	758	7	1%	4	1.18	3.4
Cliffs Branch	3,142	17	1%	4	4.91	0.8
Glen Falls Run	2,059	49	2%	24	3.22	7.5
Liberty Reservoir-B	638	9	1%	3	1.00	3.0
Keyser Run	1,006	20	2%	6	1.57	3.8
Liberty Reservoir-E	280	0	0%	0	0.44	0.0
Norris Run	1,790	48	3%	24	2.80	8.6
Liberty Reservoir-C	391	0	0%	0	0.61	0.0
Timber Run	932	11	1%	6	1.46	4.1
Cooks Branch	786	0	0%	9	1.23	7.3
Liberty Reservoir-F	2,014	0	0%	8	3.15	2.5
Chimney Branch	439	0	0%	0	0.69	0.0
Liberty Reservoir-A	786	0	0%	5	1.23	4.1
Locust Run	1,428	0	0%	0	2.23	0.0
Total	***16,449***	***160***	***1%***	***93***	***25.70***	***3.6***

*Drainage areas are not available for all minor outfalls

There is only one major outfall in the Liberty Reservoir watershed, located in the Franklin Valley neighborhood in Norris Run. The subwatershed with the highest number of total outfalls is Glen Falls Run. Most of the outfalls within the watershed have not had drainage areas delineated for them by the county, thus the drainage area and corresponding percentage of area covered are very low. The majority of the Liberty Reservoir watershed is forest, agriculture, and very low density residential, which explains the low number of inlets and outfalls in the storm drain system. Locations where inlets are present signify potential locations for management of pollution sources and community education measures such as storm drain marking.

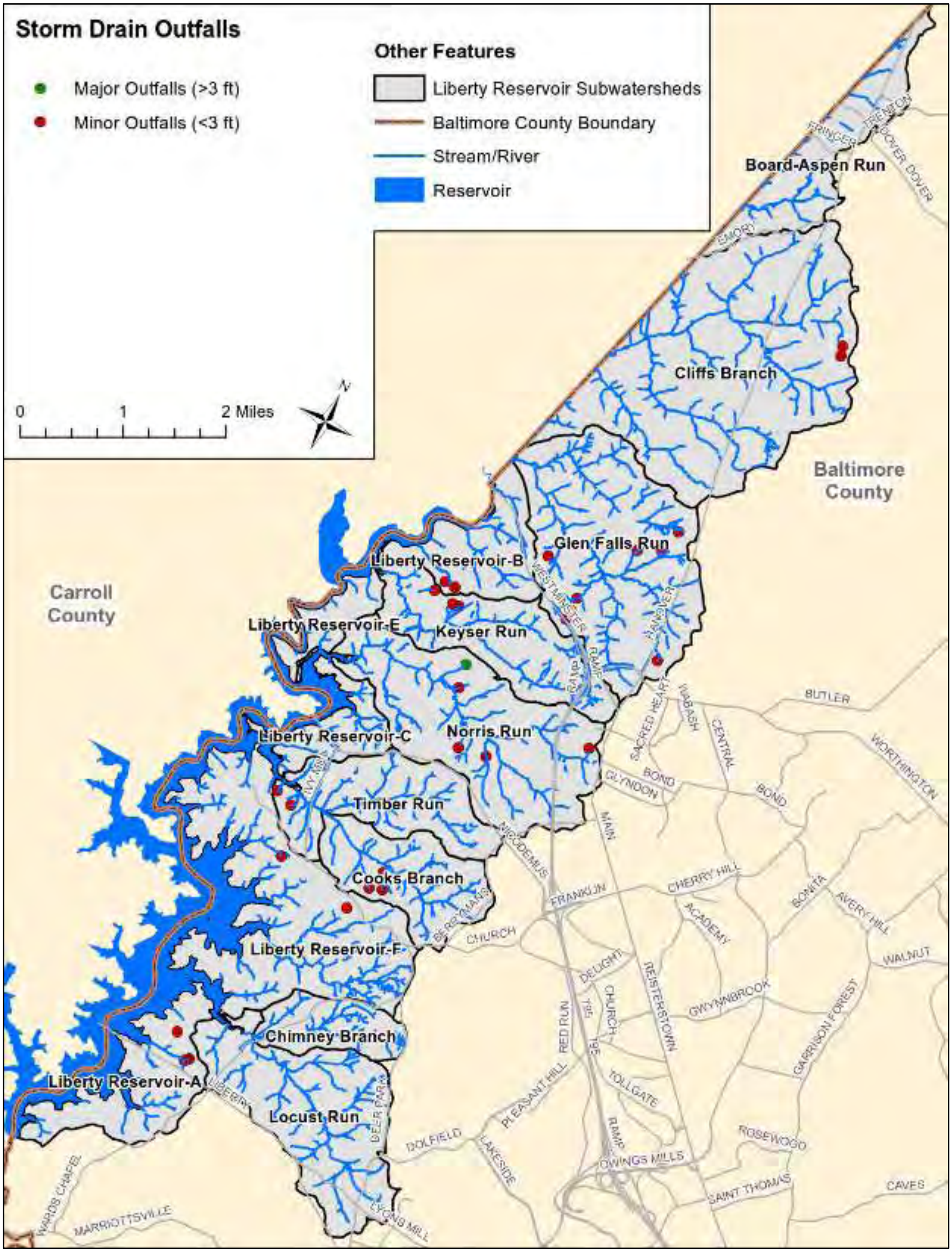

Figure 2-16: Liberty Reservoir Storm Drain Outfalls

2.3.7.2 Stormwater Management Facilities

The Maryland Department of the Environment (MDE) developed stormwater management (SWM) regulations over 25 years ago to control the quantity of runoff. SWM practices have evolved since then, and will continue to progress as new technology and research are developed. SWM is a significant consideration for new development and redevelopment within Maryland. Per Title 4, Subtitle 2, of the Environment Article of Annotated Code of Maryland, management of stormwater runoff is required to reduce erosion, sedimentation, pollution, and flooding. Increased importance of water quality and water resource protection has led to the development of the Maryland Stormwater Design Manual in 2000 to provide BMP design standards and environmental incentives, and has promoted a general shift toward low-impact SWM practices that mimic natural hydrologic processes and achieve pre-development conditions. The latter is evident by the Maryland Stormwater Management Act of 2007 which requires that Environmental Site Design (ESD) be implemented to the maximum extent practicable via nonstructural BMPs and/or other innovative design techniques.

There are many types of BMP options for managing stormwater runoff and providing stormwater quality treatment. SWM facilities can target specific objectives, depending on the BMP type, such as improving overall stormwater quality before it enters the stream, soil stabilization and erosion control, stormwater flow control or detention, and stream protection. In addition, different SWM facilities have different pollutant removal capabilities. For example, early pond designs for SWM have low pollutant removal efficiency compared to practices that filter stormwater or allow it to infiltrate into the ground or through plant roots. Considerations such as space requirements, maintenance needs, cost, and community acceptance are taken into account when selecting the appropriate stormwater treatment measures.

Table 2-17 summarizes the number of various types of public and private SWM facilities in the Liberty Reservoir watershed, including the sum of their drainage areas per subwatershed. The SWM facilities are categorized into detention ponds, wetlands, infiltration practices, filtration practices, extended detention, grassed swales and channels, and others. Figure 2-17 shows the distribution of these facilities throughout the watershed. Data for SWM facilities and their drainage areas were obtained from Baltimore County EPS.

Table 2-17: Stormwater Management Facilities in Liberty Reservoir Watershed

SWM Facility Type	Board-Aspen Run	Cliffs Branch	Glen Falls Run	Liberty Reservoir-B	Keyser Run	Liberty Reservoir-E	Norris Run	Liberty Reservoir-C	Timber Run	Cooks Branch	Liberty Reservoir-F	Chimney Branch	Liberty Reservoir-A	Locust Run	Liberty Reservoir Subtotals
Dry Pond (#)	0	1	1	0	0	0	1	0	0	0	0	0	1	1	***5***
Drainage Area (acres)	0	2	6	0	0	0	5	0	0	0	0	0	10	8	***31***
Underground Detention (#)	0	0	0	0	2	0	0	0	0	0	0	0	0	0	***2***
Drainage Area (acres)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	***1***
Wetland (#)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	***1***
Drainage Area (acres)	0	0	0	0	0	0	0	0	0	0	0	0	0	22	***22***
Infiltration (#)	0	2	9	0	3	0	6	0	3	0	0	0	0	1	***24***
Drainage Area (acres)	0	7	14	0	13	0	19	0	0	0	0	0	0	0	***53***
Filtration (#)	0	2	7	1	2	0	8	0	2	1	0	0	0	7	***30***
Drainage Area (acres)	0	5	32	1	7	0	84	0	8	9	0	0	0	50	***195***
Extended Detention (#)	0	2	3	0	3	0	5	0	5	1	0	0	0	2	***21***
Drainage Area (acres)	0	18	35	0	75	0	54	0	13	12	0	0	0	33	***239***
Grass Swales & Channels (#)	1	1	1	0	0	0	0	0	3	0	0	0	0	2	***8***
Drainage Area (acres)	0	0	2	0	0	0	0	0	8	0	0	0	0	9	***20***
Other (#)	0	3	1	0	2	0	2	0	0	0	0	0	0	2	***10***
Drainage Area (acres)	0	12	1	0	1	0	0	0	0	0	0	0	0	7	***21***
Total SWM Facilities (#)	***1***	***11***	***22***	***1***	***12***	***0***	***22***	***0***	***13***	***2***	***0***	***0***	***1***	***16***	***101***
Total Drainage Area Acres to SWM	***0***	***45***	***89***	***1***	***97***	***0***	***161***	***0***	***29***	***21***	***0***	***0***	***10***	***129***	***582***

SWM facilities are present in 10 of the 14 subwatersheds that make up the Liberty Reservoir watershed. The SWM facilities treat approximately 4% of the overall watershed area. There are no documented SWM facilities in Liberty Reservoir-E, Liberty Reservoir-C, Liberty Reservoir-F, and Chimney Branch. The most common SWM facility type is sand filter followed by extended detention facilities. Subwatersheds with the most SWM facilities tend to be those with commercial/industrial and residential land uses. Dry ponds, which typically have low pollutant rates are candidates for conversion to extended detention ponds, which have higher pollutant removal capabilities.

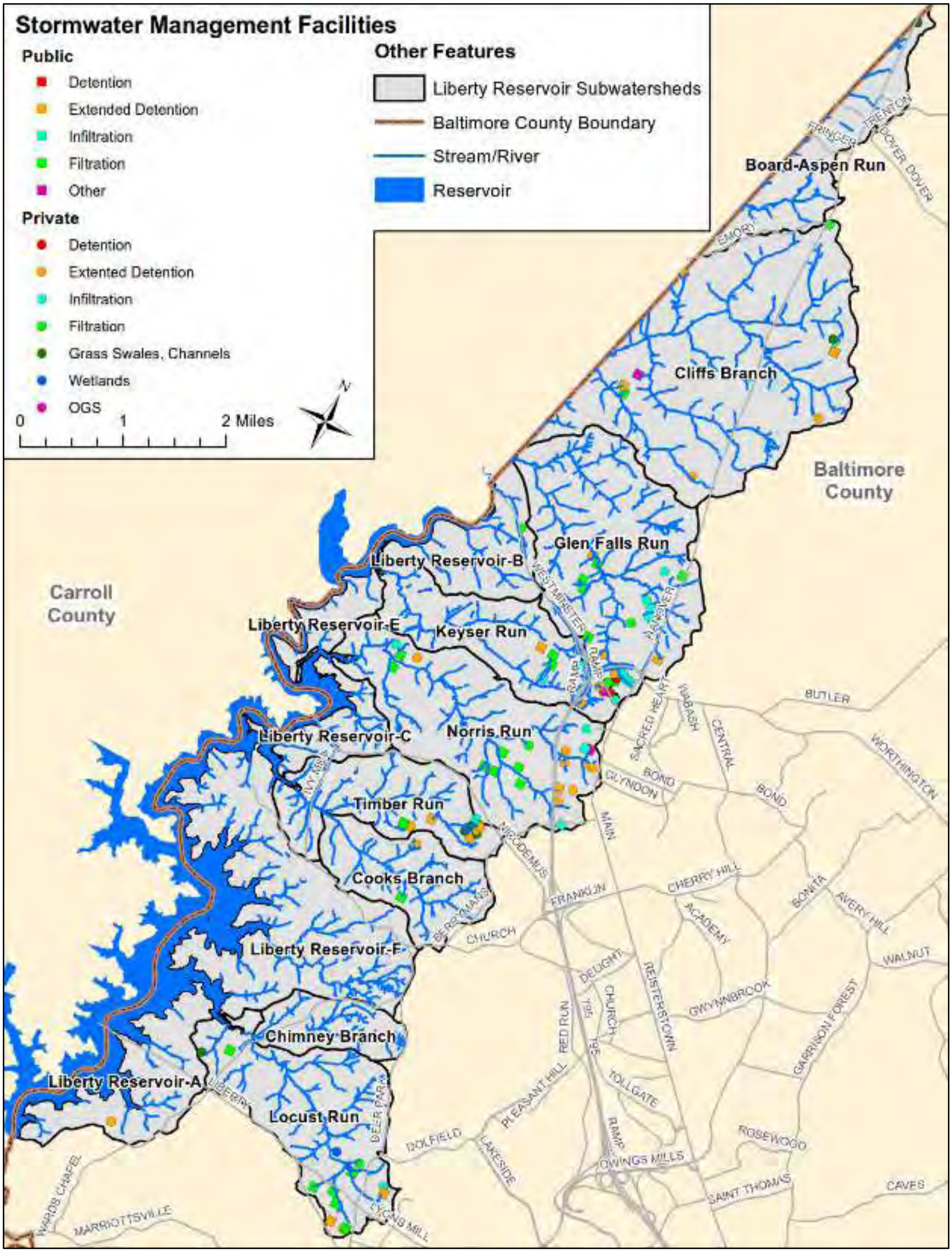

Figure 2-17: Distribution of Stormwater Management Facilities in Liberty Reservoir Watershed

Table 2-18 shows the total drainage area and the percentage of urban land treated by SWM facilities in each subwatershed. Urban land in this case refers to low, medium and high residential, commercial, industrial, institutional, open urban, and transportation land uses. This is important to evaluate because subwatersheds with high amounts of urban land but low SWM coverage percentages present opportunities for BMP implementation. BMPs can be implemented in existing developed areas with no current SWM practices or can be converted from facilities that are not providing adequate stormwater treatment. Approximately 22% of the watershed is classified as urban land and 16% of this area is treated by SWM facilities.

Table 2-18: Area Treated by Stormwater Management Facilities in Liberty Reservoir Watershed

Subwatershed	Area (Acres)	Urban Land Use (Acres)	Area Treated by SWM (Acres)	Urban Land Use Treated by SWM (%)
Board-Aspen Run	758	142	0	0%
Cliffs Branch	3,142	532	45	9%
Glen Falls Run	2,059	583	89	15%
Liberty Reservoir-B	638	174	1	0%
Keyser Run	1,006	391	97	25%
Liberty Reservoir-E	280	5	0	0%
Norris Run	1,790	586	161	27%
Liberty Reservoir-C	391	22	0	0%
Timber Run	932	212	29	14%
Cooks Branch	786	205	21	10%
Liberty Reservoir-F	2,014	228	0	0%
Chimney Branch	439	58	0	0%
Liberty Reservoir-A	786	90	10	11%
Locust Run	1,428	316	129	41%
Total	***16,449***	***3,545***	***582***	***16%***

2.3.8 NPDES Discharge Permits

Businesses and other facilities that discharge municipal or industrial wastewater or conduct activities that can contribute pollutants to a waterway are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit. The type of NPDES permit required depends on the nature of the activities conducted by the facility. Table 2-19 summarizes the number of facilities holding NPDES permits in the Liberty Reservoir watershed by subwatershed and permit type. Cliffs Branch and Glen Falls Run both have one facility with three permits; all permits are reported in the table.

Table 2-19: NPDES-Permitted Facilities in Liberty Reservoir Watershed

Subwatershed	# General Industrial Stormwater Permits	# Surface Industrial Discharge Permits	# Groundwater Municipal Discharge Permits	# General Permits	Total # of Permits in Subwatershed
Board-Aspen Run	0	0	0	0	0
Cliffs Branch	1	2	0	0	3
Glen Falls Run	1	1	1	0	3
Liberty Reservoir-B	0	0	0	0	0
Keyser Run	0	0	0	0	0
Liberty Reservoir-E	0	0	0	0	0
Norris Run	1	0	0	1	2
Liberty Reservoir-C	0	0	0	0	0
Timber Run	1	0	0	0	1
Cooks Branch	0	0	0	0	0
Liberty Reservoir-F	0	0	0	0	0
Chimney Branch	0	0	0	0	0
Liberty Reservoir-A	0	0	0	0	0
Locust Run	0	0	0	0	0
Total	***4***	***3***	***1***	***1***	***9***

The federal NPDES permits listed above also function as MDE water management permits. Descriptions of each type of NPDES permit are provided as follows by MDE:

- **General Industrial Stormwater Permits** are required for industrial facilities discharging stormwater to storm drains or surface waters.
- **Surface Industrial Discharge Permits** are required for industrial facilities that discharge any wastewater to any place other than the sanitary sewer.
- **Groundwater Municipal Discharge Permits** are required for municipal facilities discharging any wastewater to the groundwaters of the State.
- **General Permits** are required for facilities discharging wastewater or stormwater to any place other than a sanitary sewer, or for any manufacturing, fleet vehicle, or recycling facility.

NPDES permit data for the Liberty Reservoir watershed was estimated from spatial data provided by Baltimore County EPS, based on 2010 MDE records. As of 2010, there are a total of 5 facilities holding NPDES permits in the Liberty Reservoir watershed (two of which hold three permits). The facilities holding NPDES permits include large institutional facilities (Camp Fretterd Military Reservation and Pearlstone Family Camp), a transportation facility (Baltimore County maintenance shop 3), Green Valley Swim Club, and an apartment complex (Glyndon Trace Condominiums). The subwatersheds with the most NPDES permitted facilities Glen Falls Run and Cliffs Branch, each with three permits. Figure 2-18 shows the locations of NPDES-permitted facilities in the Liberty Reservoir watershed.

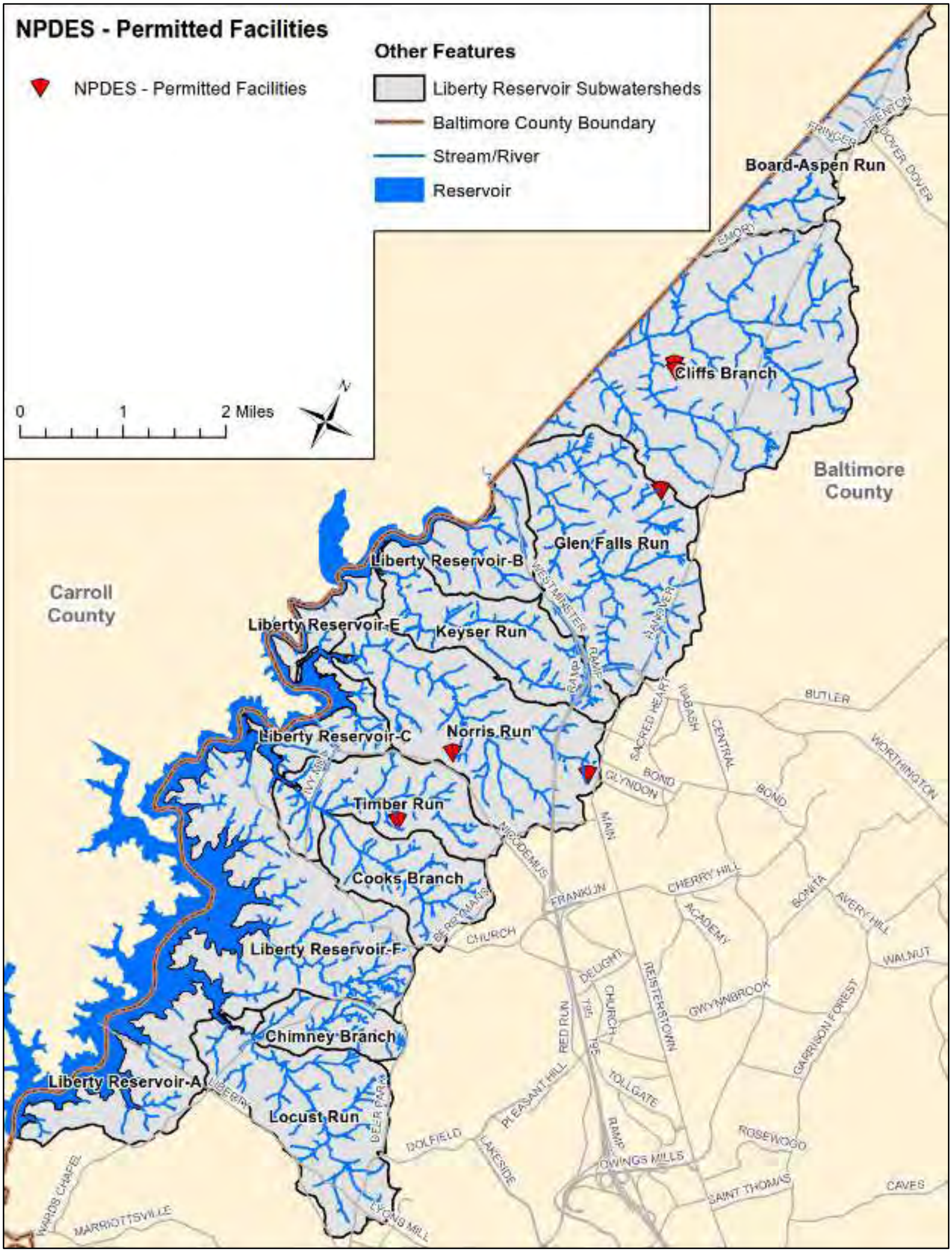

Figure 2-18: Location of NPDES-Permitted Facilities in Liberty Reservoir Watershed

2.3.9 Agricultural Best Management Practices (BMPs)

Current agricultural best management practices (BMPs) being used in the Liberty Reservoir watershed was available through the Baltimore County Soil Conservation District (SCD) on the 12-digit watershed scale. Liberty Reservoir is encompassed by three 12-digit watersheds as shown in Figure 2-19.

The agricultural BMPs provided by the SCD were divided and reported for the watershed based on their broader functions. The primary agricultural BMP functions within the watershed include waste storage, cover crops and land management activities, habitat improvement, animal control for waterways, erosion control, and nutrient reduction. For a complete list of BMPs and their reclassification see Table 2-20. The agricultural BMPs for the three 12-digit subwatersheds encompassing Liberty Reservoir are summarized below in Table 2-23. Within Baltimore County, agricultural BMPs have been implemented in both the 021309071048 and 021309071046 watersheds while there are currently zero agricultural BMPs in subwatershed 021309071058.

Table 2-20: Reclassification of BMPs to Functional Classifications for Liberty Reservoir Watershed

Waste Storage	Cover Crops/ Land Management	Habitat Improvement	Animal Control (to waterways)	Erosion Control	Nutrient Reduction
Waste Storage Facility	Forage Harvest Management	Critical Area Planting	Fence	Heavy Use Area Protection	Nutrient Management
		Riparian Forest Buffer	Livestock Pipeline	Roof Runoff Structure	
			Streamside Fence (10'-34')		
			Non Streamside Fence		
			Spring Development		
			Watering Facility		
			Watercourse Exclusion		

Table 2-21: Agricultural BMPs in the Liberty Reservoir Watershed

	Waste Storage	Cover Crops/ Land Management	Habitat Improvement		Animal Control (to waterways)			Erosion Control		Nutrient Reduction
Subshed	(No.)	(Ac.)	(Ac.)	(Ac.)	(Ft.)	(No.)	(Ac.)	(Ft.)	(No.)	(Ac.)
021309071**046**	1	0.0	0.8	0.0	3,250	1	0.1	0.0	1	0.0
021309071**048**	0	9.5	2.7	0.0	8,196	3	0.0	0.0	0	2.1
021309071**058**	0	0.0	0.0	0.0	0	0	0.0	0.0	0	0.0
Total	***1***	***9.5***	***3.5***	***0.0***	***11,446***	***4***	***0.1***	***0.0***	***1***	***2.1***

*Multiple BMPs can be applied to the same area of land; totals do not take into account overlapping BMPs

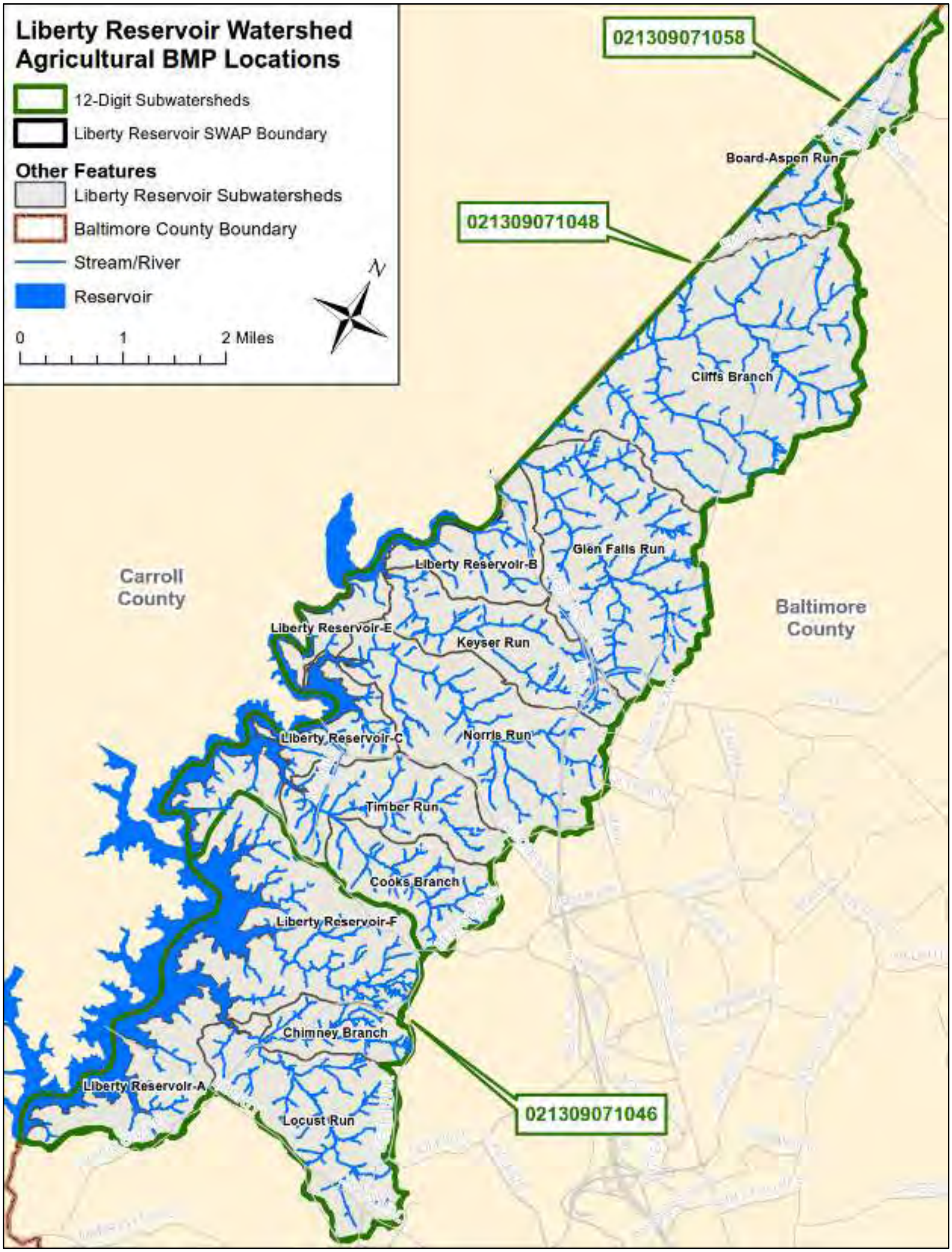

Figure 2-19: Agricultural BMPs within 12-digit Subwatersheds and Liberty Reservoir Watershed

2.3.10 Zoning

The Baltimore County Office of Planning defines zoning as "a system of land use regulation that controls the physical development of land and a legal mechanism by which local government is able to regulate an owner's right to use privately owned land for the sake of protecting the public health, safety, and/or general welfare" (DP, 2013). In other words, zoning manages development patterns over time throughout the county. Table 2-22 shows the various zoning categories present in the Liberty Reservoir watershed.

As shown in Figure 2-20, a significant portion of Liberty Reservoir watershed is under watershed protection (36%), resource preservation zoning (23%) and environmental enhancement (10%) zoning. The watershed also has a noteworthy percentage of agricultural zoning (25%).

Table 2-22: Baltimore County Zoning in Liberty Reservoir Watershed

Zoning Code	Zoning Description	Total Acres	% of Watershed Area
DR 1	Density Residential--1 unit/acre	93	0.6%
DR 2	Density Residential--2 units/acre	44	0.3%
DR 3.5	Density Residential--3.5 units/acre	307	1.9%
DR 5.5	Density Residential--5.5 units/acre	0	0.0%
DR 10.5	Density Residential--10.5 units/acre	47	0.3%
DR 16	Density Residential--16 units/acre	1	0.0%
RC 2	Agricultural	4,112	25.0%
RC 3	Deferral of Planning and Development	7	0.0%
RC 4	Watershed Protection	5,958	36.2%
RC 5	Rural Residential	300	1.8%
RC 7	Resource Preservation	3,719	22.6%
RC 8	Environmental Enhancement	1,656	10.1%
RCC	Resource Conservation Commercial	9	0.1%
Commercial	Office/Business	189	1.2%
Industrial	Manufacturing	5	0.0%
Total		***16,449***	***100.0%***

As presented in Table 2-22, approximately 69% of the Liberty Reservoir watershed is zoned for protection, preservation, or enhancement while agricultural zoning covers approximately 25% of the watershed. Industrial and commercial use zones are permitted in approximately 1% of the Liberty Reservoir watershed. The remaining 5% of land is zoned residential.

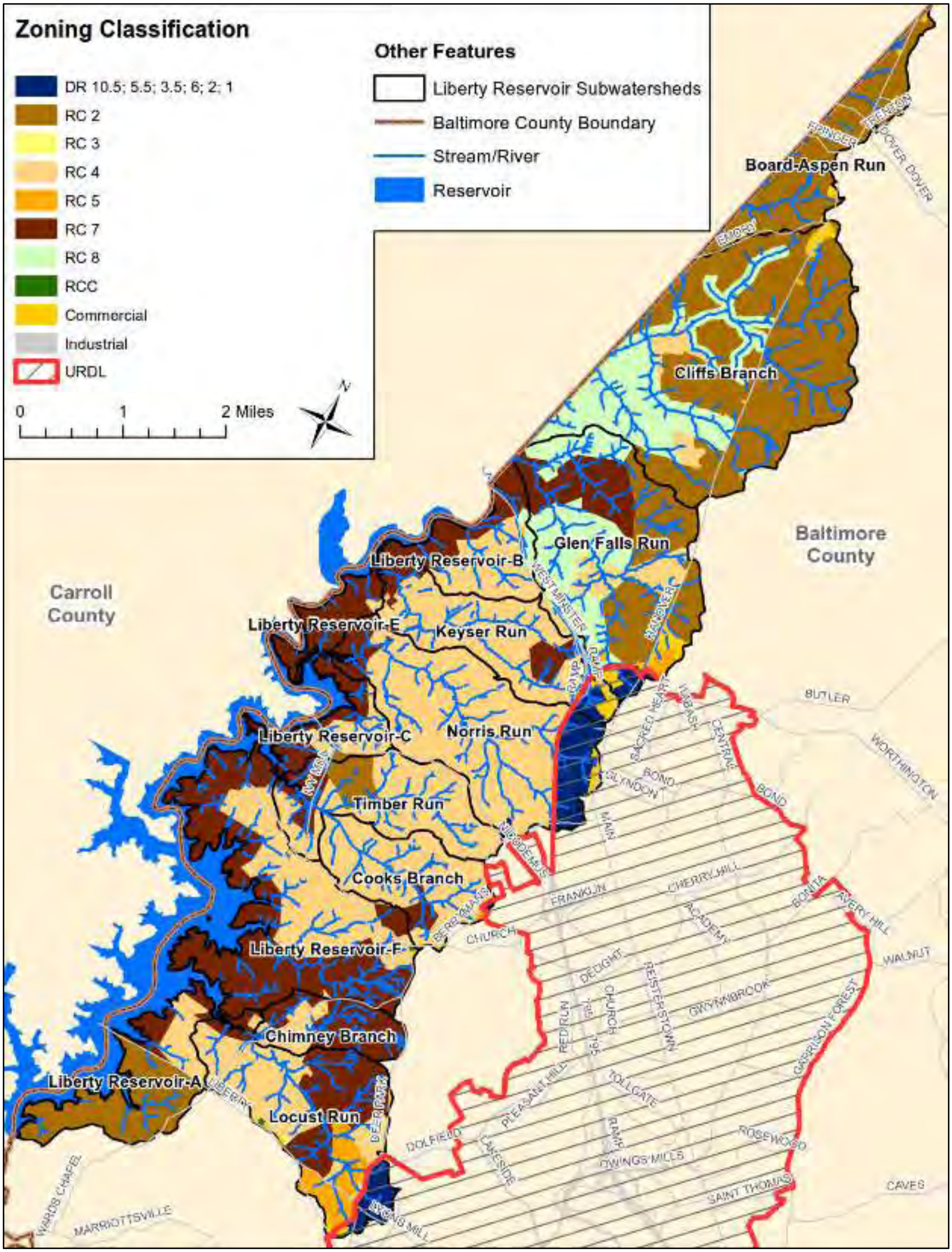

Figure 2-20: Liberty Reservoir Zoning

2.3.10.1 Resource Conservation Areas

There are multiple programs working to conserve land in the Liberty Reservoir watershed. Analysis of conservation areas within the watershed was conducted using GIS data provided by Baltimore County EPS. Overall, 43% of the watershed is located in a conservation area. Cliffs Branch has the most land in easements, with 1,603 acres; however, Liberty Reservoir-E has the greatest percentage of land in easements (84%). Table 2-23 summarizes the conservation easements located in each subwatershed, and Figure 2-21 illustrates the easement distribution in the watershed. There is some overlap in conservation easements, mainly DNR protected land that is located in an additional easement. Many properties are co-held under multiple easements; however, the values reflected in the total column of Table 2-21 only show the land area covered in easements.

Baltimore County has ten resource conservation zones, of which, seven are currently being applied to land within the County (Table 2-22). The Liberty Reservoir has one category, RC 4, which contains a resource conservation easement. Resource conservation easements are used to protect agricultural land, rural residential development, rural commercial development, and natural resources. The RC 4 (Watershed Protection) zoning requires 70% of the tract acreage be allocated as a conservancy area (DP, 2006). Five percent of the Liberty Reservoir watershed (821 acres) is in RC4 easements, with over 70% of the conservation easements located in the Cliffs Branch, Timber Run, and Cooks Branch subwatersheds.

In addition to zoning conservation efforts, the Baltimore County Agricultural Land Preservation Program aims to create easements to preserve working family farms located within the Agricultural Preservation Protection Areas. The Liberty Reservoir watershed has 149 acres of county agricultural easements with the majority of the easements in Cliffs Branch, Timber Run, and Cooks Branch. County forest conservation easements protect 1,191 acres of forest land throughout the watershed as required by the Forest Conservation Act of 1991. The only subwatersheds without county forest conservation easements are Liberty Reservoir-E and Chimney Branch.

The Federal Farm and Ranch Program is another program used to keep productive farm and ranchland in agricultural use. The watershed has five easements under this program, protecting 402 acres within the Cliffs Branch subwatershed.

Local land trusts are another method of land conservation whereby the landowner may donate or sell part of their land to a land trust as a conservation easement. In the Liberty Reservoir watershed, the Land Preservation Trust is a non-profit organization that focuses on the preservation of farms, forests, and historical landmarks in the watershed. There are currently 25 acres in conservation easements in three subwatersheds, Cliffs Branch, Keyser Run, and Norris Run.

There are also multiple state led conservation efforts within the watershed. The Maryland Agricultural Land Preservation Foundation (MALPF) is a cooperative program of the county and Maryland Department of Agriculture (MDA) that protects agricultural land and woodland through the use of perpetual easements. This program accounts for 4% of all easements in the watershed.

The Maryland Environmental Trust (MET) is a statewide land trust whose goal is the preservation of open land, including farmland, forest land, and significant natural resources. This is achieved mainly through the use of a conservation easement, which is a perpetual agreement between the landowner and MET ensuring that the property shall not be developed beyond a limit agreed upon by both parties.

The Rural Legacy Program is a state program that was adopted and additionally funded by the county to protect Maryland's rural landscapes and natural areas through the purchase of land or conservation easements. The program emphasizes the protection of large blocks of rural agricultural and forested land.

The Maryland Department of Natural Resources (DNR) manages and protects 1,900 acres of serpentine barren within Soldiers Delight Natural Environmental Area (NEA). Approximately 1,296 acres of this area falls within the Liberty Reservoir watershed. Efforts are currently being made to preserve rare, threatened, and endangered species in Soldiers Delight NEA.

In addition to conservation areas, Baltimore City owns and manages approximately 2,105 acres of land along the Baltimore County side of the Liberty Reservoir for the purpose of protecting the reservoir. The area is open to the public for hiking, horseback riding, and other recreational purposes.

Table 2-23: Liberty Reservoir Conservation Easements (Acres)

Subwatershed	DNR Lands & Conservation Easements	Forest Conservation	County Agricultural Land Preservation	Federal Farm and Ranch Protection	Local Land Trust	MD Ag Land Preservation Foundation	MD Environmental Trust	RC4 (Watershed Protection Zoning)	Rural Legacy	Reservoir Lands	Total*	% of Easement in Subwatershed
Board-Aspen Run	0.0	6.7	0.0	0.0	0.0	258.9	0.0	0.0	4.0	0.0	***269.6***	***36%***
Cliffs Branch	0.0	321.4	101.2	401.5	8.3	334.3	21.7	342.0	72.5	0.0	***1,356.1***	***43%***
Glen Falls Run	0.0	323.0	0.0	0.0	0.0	0.0	0.0	84.8	0.0	83.4	***439.3***	***21%***
Liberty Reservoir-B	0.0	30.7	0.0	0.0	0.0	0.0	0.0	62.1	0.0	239.2	***306.8***	***48%***
Keyser Run	0.0	25.9	0.0	0.0	14.4	0.0	62.8	14.0	0.0	60.9	***174.0***	***17%***
Liberty Reservoir-E	0.0	0.0	0.0	0.0	0.0	0.0	107.6	0.0	0.0	127.0	***234.6***	***84%***
Norris Run	0.0	215.3	0.0	0.0	1.9	0.0	58.1	14.6	0.0	79.6	***369.4***	***21%***
Liberty Reservoir-C	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	211.3	***216.3***	***55%***
Timber Run	0.0	127.6	14.3	0.0	0.0	0.0	0.0	107.2	0.0	97.0	***269.0***	***29%***
Cooks Branch	124.6	84.4	33.0	0.0	0.0	0.0	61.6	135.0	0.0	0.0	***310.7***	***40%***
Liberty Reservoir-F	504.9	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	745.6	***1,254.9***	***62%***
Chimney Branch	321.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.6	***326.3***	***74%***
Liberty Reservoir-A	0.0	6.7	0.0	0.0	0.0	0.0	0.0	4.5	0.0	414.5	***422.4***	***54%***
Locust Run	345.2	40.0	0.0	0.0	0.0	69.0	105.7	56.3	0.0	41.4	***620.5***	***43%***
Total	***1,296.4***	***1,191.3***	***148.5***	***401.5***	***24.6***	***662.2***	***417.5***	***820.5***	***76.5***	***2,104.6***	***6,570.1***	***40%***
% of Liberty Reservoir Watershed in Easement	***8%***	***7%***	***1%***	***2%***	***0%***	***4%***	***3%***	***5%***	***0%***	***13%***	***40%***	

*The total does not double count land that was included in multiple easements

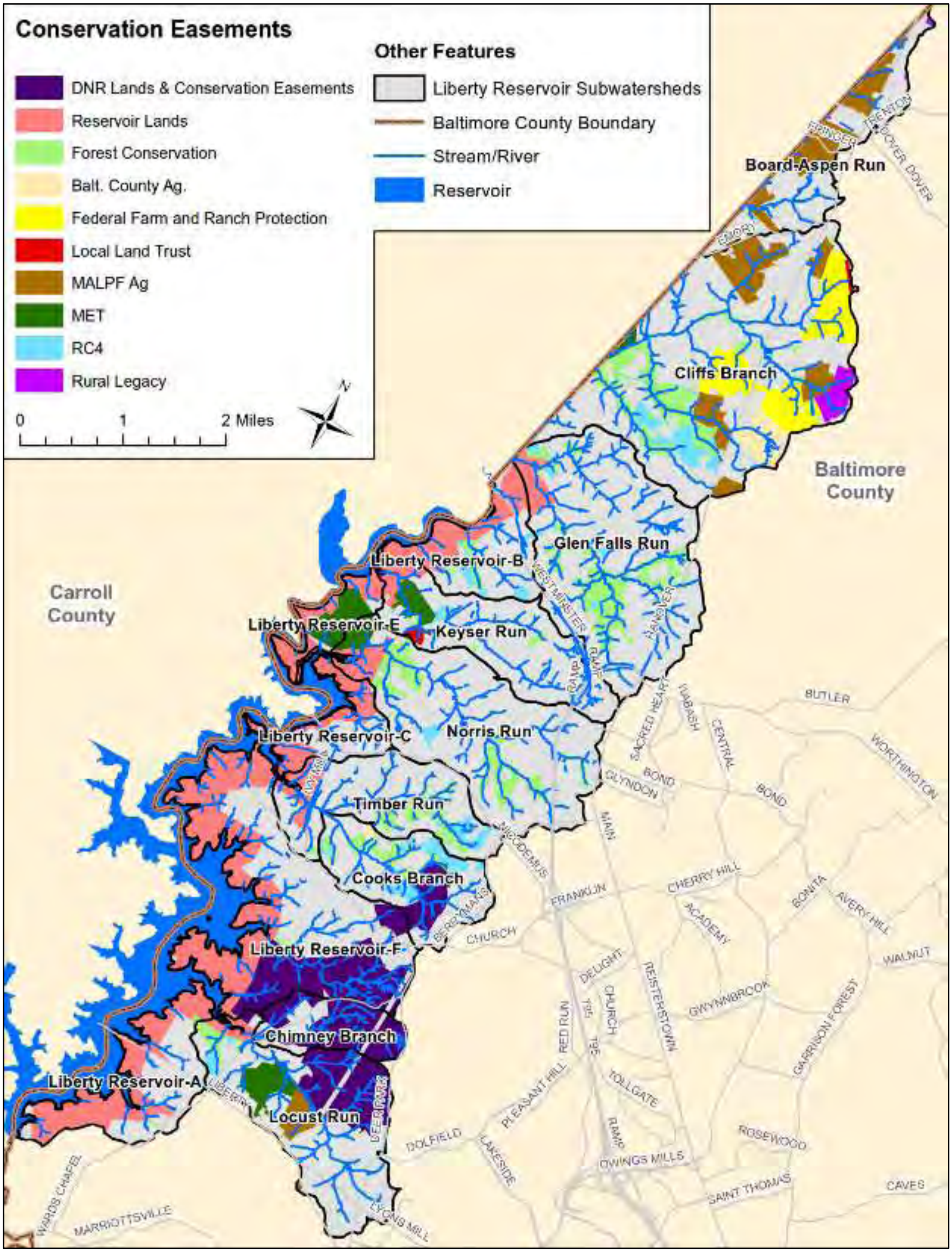

Figure 2-21: Resource Conservation Easements

2.3.11 Historical Development

Historical development within Liberty Reservoir began before the 1800s. There has been steady growth throughout the watershed with the peak of development from 2000 to 2009. Using GIS tax parcel data provided by the Baltimore County OIT, the decade each parcel of land was built was derived for the watershed. A summary of these parcels and their build date are shown in Table 2-24 and Figure 2-22. Parcels constructed prior to 1920 were categorized on a broader time step as shown. Figure 2-23 illustrates the historical development throughout the Liberty Reservoir watershed. A significant portion of land parcels are undeveloped or do not have tax parcel data associated with them.

Table 2-24: Decade Built and Number of Parcels

Subwatershed	1700s	1800s	1900 to 1910	1910s	1920s	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000 to 2009	2010 or after	No Data	Undeveloped
Board-Aspen Run	0	12	17	11	11	1	6	30	13	15	15	17	15	0	40	69
Cliffs Branch	0	32	18	7	17	9	34	79	45	31	36	49	85	1	99	147
Glen Falls Run	0	16	15	9	21	15	7	45	37	50	39	46	63	2	65	103
Liberty Reservoir-B	0	1	1	1	0	0	1	6	15	9	8	38	23	0	10	20
Keyser Run	0	4	2	2	3	3	9	20	29	32	21	121	60	0	37	82
Liberty Reservoir-E	0	0	0	0	0	0	2	2	2	0	0	1	0	0	14	4
Norris Run	0	20	13	2	25	9	21	51	20	93	50	85	297	1	121	189
Liberty Reservoir-C	0	0	0	0	1	0	2	2	2	3	4	10	12	0	12	10
Timber Run	0	1	0	0	4	1	8	9	14	51	15	18	60	0	28	55
Cooks Branch	0	3	6	1	11	5	5	26	8	21	22	21	42	0	30	72
Liberty Reservoir-F	0	7	6	2	3	9	2	16	13	50	44	8	17	1	61	74
Chimney Branch	0	2	1	0	1	2	10	9	4	2	1	0	0	0	8	28
Liberty Reservoir-A	0	2	2	2	3	2	6	8	4	3	20	12	1	0	34	39
Locust Run	1	12	8	12	15	21	46	106	32	15	21	16	11	0	42	157
Total	***1***	***112***	***89***	***49***	***115***	***77***	***159***	***409***	***238***	***375***	***296***	***442***	***686***	***5***	***601***	***1,049***

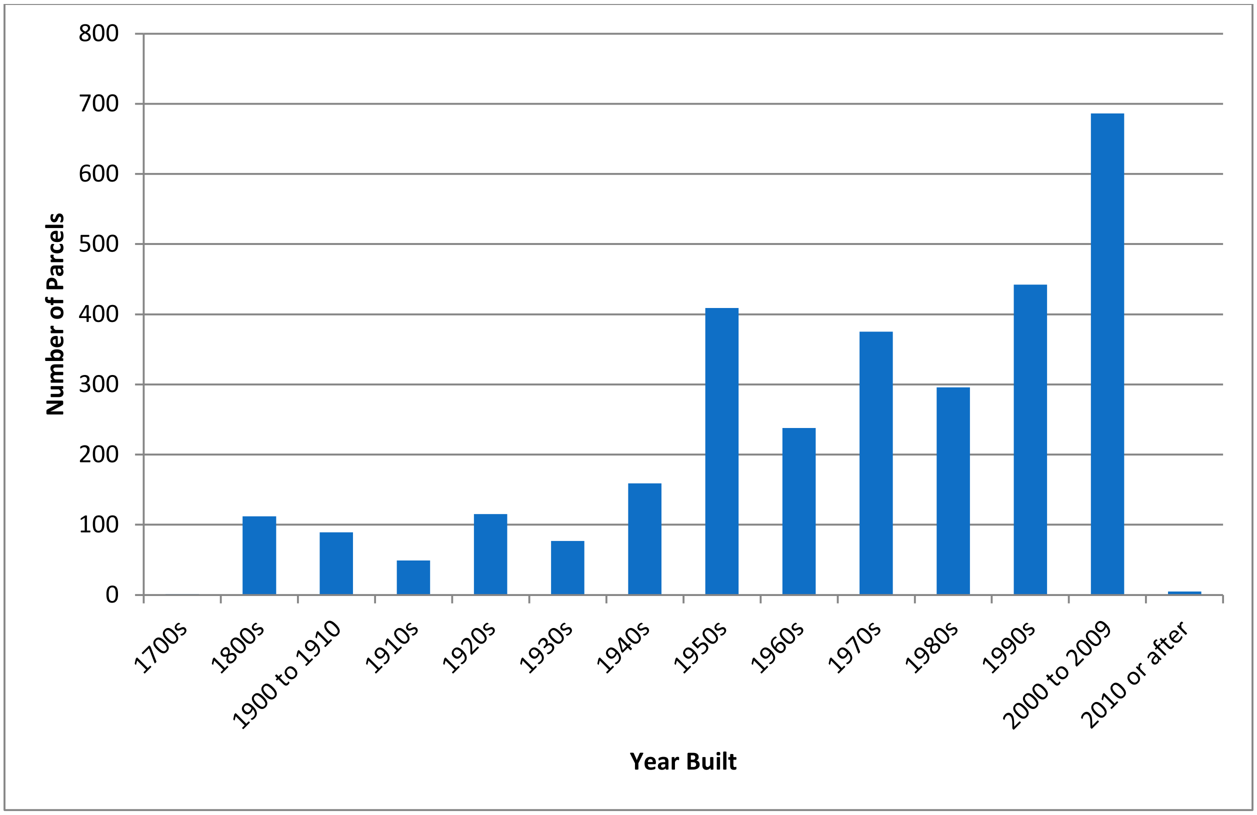

Figure 2-22: Number of Parcels Built Over Time

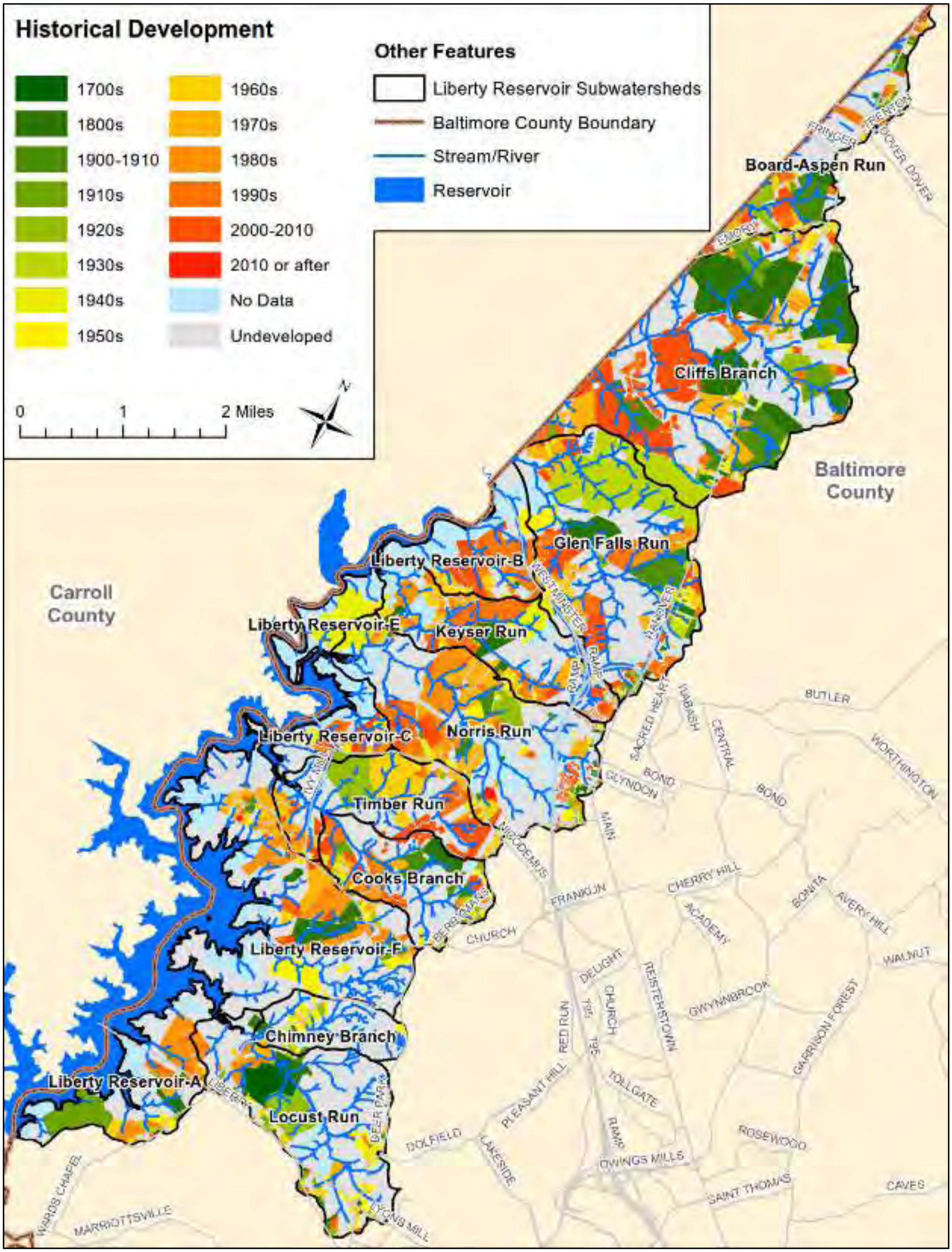

Figure 2-23: Historical Development throughout Liberty Reservoir

CHAPTER 3: WATER QUALITY AND LIVING RESOURCES

3.1 Introduction

Water is an integral part of all habitats. The Small Watershed Action Plan (SWAP) goals for maintaining and improving water quality also aim to provide for flora, fauna, and their habitats. Because habitat conditions affect the ability of natural communities to find food and shelter and carry on natural processes, it is necessary to evaluate the state of existing land, water, and biological elements that provide for their needs. This chapter describes the water quality, living resources, and habitats for the Liberty Reservoir watershed based on existing conditions.

Living resources, including all plants and animals, require water for survival. They are intimately connected to and respond sensitively to water quality and habitat conditions. Their dependence on water quality can provide a gauge with which to measure and evaluate the status of water bodies and the effects that watershed characteristics and upland activities have on these water bodies. For example, in addition to taking direct measurements of a pollutant, water quality can be measured in terms of its ability to support living resources, such as trout or shellfish. Information on living resources is presented in this chapter to indicate water quality status and to evaluate habitat conditions in the Liberty Reservoir watershed. This information can help to determine if current watershed management practices are adequately providing for the needs of the natural communities.

The following sections include descriptions of the following with respect to the Liberty Reservoir watershed: impairments per Maryland state water quality standards, pollutant loading analysis for total nitrogen, total phosphorus and sediment, water quality monitoring data available to date, stream corridor assessments, and mill dam assessments.

3.2 303(d) Listings and Total Maximum Daily Loads (TMDLs)

The Clean Water Act (CWA) requires states, territories, and authorized tribes to: develop water quality standards for all jurisdictional surface waters; monitor these surface waters; and identify and list impaired waters. More specifically, Section 305(b) of the CWA requires annual water quality assessments to determine the status of jurisdictional waters. Section 303(d) requires states to identify and periodically update a list of impaired waters that fail to meet applicable state water quality standards. States must also establish priority rankings and develop Total Maximum Daily Loads (TMDLs) for waters on the 303(d) list, which generally target pollutants including sediment, metals, bacteria, nutrients, and pesticides. According to the United States Environmental Protection Agency (USEPA), a TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet state water quality standards.

Water quality standards are developed from a combination of the designated use for a given water body and the water quality criteria designed to protect that use. Table 3-1 provides the definition for each designated class.

Table 3-1: Maryland's Designated Uses for Surface Waters

Class	Definition
Use I	Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life
Use I-P	Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply
Use II	Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting
Use II-P	Tidal Fresh Water Estuary – includes applicable Use II and Public Water Supply
Use III	Nontidal Cold Water
Use III-P	Nontidal Cold Water and Public Water Supply
Use IV	Recreational Trout Waters
Use IV-P	Recreational Trout Waters and Public Water Supply

A portion of the surface waters (e.g. streams) within the Liberty Reservoir watershed, including Norris Run, Cooks Branch, Keyser Run, Locust Run, Glen Falls Run and all their tributaries, are designated as Use III-P – nontidal cold water and public water supply (COMAR, 2014a). All other surface waters in the watershed upstream of Liberty Dam, including Liberty Reservoir and the remaining tributaries are designated as Use I-P – water contact recreation, protection of aquatic life, and public water supply (COMAR, 2014a).

Based on the water quality criteria associated with the above designated uses, the Liberty Reservoir watershed is listed in *Maryland's Integrated Report (IR) of Surface Water Quality* for various pollutants of concern. Each listing is applicable to the Liberty Reservoir (basin 02130907). Each listing within the IR is sorted by attainment status or category upon which a water body is placed. Table 3-2 provides the definition for each attainment status or listing category within the report (MDE, 2012a).

Table 3-2: Maryland Integrated Report Listing Categories (MDE, 2012a)

Listing Category	Definition
2	Waters meeting the standards for which they have been assessed
3	Waters that have insufficient data or information to determine whether any water quality standard is being attained
4a	Waters that are still impaired but have a TMDL developed that establishes pollutant loading limits designed to bring the waterbody back into compliance
4b	Waters that are impaired but for which a technological remedy should correct the impairment

4c	Waters that are impaired but not for a conventional pollutant. This includes pollution caused by habitat alteration or flow limitations
5	Water bodies that may require a TMDL

Maryland's IR is updated every two years. While Maryland's Final 2012 IR is the latest finalized report, Maryland's Draft 2014 IR is currently under review by the USEPA and is available for viewing at this time. Once the USEPA approves the IR, it will become the Final 2014 IR. The Liberty Reservoir impoundment and stream segments are listed in the Maryland's Final 2012 IR and for the following water quality impairments: fecal bacteria (Escherichia coli), sediment, mercury, chlorides, and phosphorus (MDE, 2012a). In the 2014 Draft IR, temperature was also listed (MDE, 2014a). Impairment listings within categories 4a, 4b, 4c, or 5 reflect an inability to meet water quality standards. When a stream segment or impoundment is listed as impaired, action can be taken by developing and/or adhering to a TMDL or by submitting a Water Quality Analysis (WQA) to remove a specific pollutant from the impairment listing. TMDLs can be developed for a single pollutant or group of pollutants of concern. WQAs are performed to determine if the pollutant of concern is actually the cause of the impairment. If it is determined that the pollutant of concern is not causing the impairment, a report documenting the findings is submitted to the USEPA for concurrence. Maryland's 2012 IR represents a fully combined 303(d) and 305(b) report approved by USEPA (MDE, 2012a). Maryland's 2014 Draft IR is pending approval by USEPA (MDE, 2014a).

Table 3-3 summarizes the status of the current listings for portions of the Liberty Reservoir watershed that are applicable to the current SWAP area.

Table 3-3: Liberty Reservoir Water Quality Impairment Listings and Status

Impairment	Applicable Segment	2012 Final Integrated Report Listing Category	Status	Approval Date	2014 Draft Integrated Report Listing Category	Status	Approval Date
Escherichia coli	MD-02130907	4a	TMDL	2009	4a	TMDL	2009
Sedimentation/ siltation	MD-02130907	5	Impaired	N/A	4a	TMDL	2014
Phosphorus	MD-02130907	5	Impaired	N/A	4a	TMDL	2014
Mercury	MD-02130907	5	Impaired	N/A	2	Removed	2014
Chlorides	MD-02130907	5	Impaired	N/A	5	Impaired	N/A
Temperature	MD-021309071046-Locust Run	-	-	-	5	Impaired	N/A
Temperature	MD-021309071048-Keyser Run	-	-	-	5	Impaired	N/A
Temperature	MD-021309071048-Timber Run	-	-	-	5	Impaired	N/A
Temperature	MD-021309071048-Glen Falls Run	-	-	-	5	Impaired	N/A

As shown in Table 3-3, there are currently (2012 IR) five listings for the Liberty Reservoir watershed. The *E. Coli* listing was placed under category 4a, meaning a TMDL has been completed for this impairment.

Pending the approval of the 2014 IR, the sedimentation/siltation and phosphorus impairments will also be moved from a category 5 listing to category 4a, due to the approval of TMDLs for these pollutants in 2014 (MDE, 2014a). A WQA was also approved in 2014 for mercury, indicating the concentration of mercury in fish tissue falls below the water quality standard (MDE, 2014d). The results of the WQA are reflected in the Draft 2014 IR with the shift from category 5 to category 2 for mercury (MDE, 2014a). A biological impairment was listed under category 5 in 2004 with an unknown source. A biological stressor identification (BSID) analysis was developed in 2012 to determine the cause of biological impairments. The BSID analysis determined the cause of degraded biological communities to be inorganic pollutants (chlorides and conductivity) (MDE, 2012b). As a result of the BSID study, the biological impairment was updated to a chloride impairment in the 2012 IR. The Draft 2014 IR has four additional impairments listed under category 5 for temperature with an unknown source (MDE, 2014a). In all four listings, temperature was observed above criteria and no coldwater obligate taxa were found.

In addition to the impairments listed for the watershed, Liberty Reservoir has three additional listings. Chromium, lead, and polychlorinated biphenyl (PCB) in fish tissue were listed under Category 2, meaning the reservoir meets the criteria for these pollutants, as documented in a WQA accepted in 2003 for chromium and lead (MDE, 2003). PCBs were listed with concentrations below the threshold and therefore a Water Quality Report was not required.

3.2.1 Bacteria (*E. Coli*) TMDL

A bacteria TMDL was developed for the entire Liberty Reservoir watershed, encompassing both the Carroll County and Baltimore County drainage areas (MDE, 2009). Sampling from five representative stations located in the Carroll County portion of the Liberty Reservoir watershed was used to estimate a baseline load for *E. coli*. High flows and low flows for annual and seasonal conditions were then used to determine the TMDL load, which is reported in the units of Most Probable Number (MPN) per day. The *E. coli* TMDL for the entire Liberty Reservoir watershed (including a substantial portion located in Carroll County) is 361,008 billion MPN *E.coli* /year. The Liberty Reservoir was split into 6 subwatersheds for the purpose of developing the Bacteria TMDL. The portion of Liberty Reservoir watershed located within Baltimore County is contained within the “Downstream Subwatershed”, which also encompasses portions of Carroll County. Since there are no sampling stations within the downstream watershed, the average of the five upstream bacteria concentrations was assumed to be representative of the downstream subwatershed. The E. coli TMDL for the “Downstream Subwatershed” is 110,313 billion MPN *E.coli* /year (MDE, 2009).

The bacteria TMDL is split between load allocations (LA) for nonpoint sources in each of the six TMDL subwatersheds and waste load allocations (WLA) for point sources including NPDES regulated stormwater (SW) and wastewater treatment plants (WWTPs). The final TMDL is split between LA (350,638 billion MPN *E. coli*/year), WLA from SW (9,325 billion MPN *E. coli*/year), and WLA from WWTP (1,045 billion MPN *E. coli*/year). The “Downstream Watershed” portion of the TMDL is split between LA (105,988 billion MPN *E. coli*/year), WLA from SW (4,325 billion MPN *E. coli*/year), and WLA from WWTP (0 billion MPN *E. coli*/year). To meet the final TMDL, the entire Liberty Reservoir watershed LA must be reduced 67% from its baseline load (MDE, 2009). The TMDL calls for implementation of maximum practical reductions to reduce fecal bacteria loads. In addition, other BMPs will be needed to meet reduction requirements including public education on pet waste, management of overpopulation of wildlife, and addressing failing septic systems in the watershed (MDE, 2009).

3.2.2 Sediment and Phosphorus TMDL

The TMDLs for phosphorus and sediment apply to the entire 104,800-acre Liberty Reservoir watershed which encompasses portions of western Baltimore County and eastern Carroll County. As such, the TMDLs and reductions presented are for Liberty Reservoir watershed as a whole. The total phosphorus (TP) TMDL is 41,009 lbs. /yr. (46% reduction), and the sediment TMDL is 15,988 tons/yr. (23%) reduction (MDE, 2014c). Each of these TMDLs includes nonpoint source loads from unregulated stormwater runoff within the Liberty Reservoir watershed along with point source loads from industrial facilities that discharge process water, National Pollutant Discharge Elimination System (NPDES) for regulated stormwater discharges, and Confined Animal Feeding Operations (CAFOs). The Baltimore County urban stormwater load is responsible for reducing its phosphorus loading by 49% and its sediment loading by 38% (MDE, 2014e).

3.2.3 Chlorides Impairment

Chlorides were found in 55% of stream miles with very poor to poor biological conditions during a BSID analysis for the Liberty Reservoir watershed encompassing Carroll and Baltimore counties (MDE, 2012b). High concentrations of chlorides are toxic to aquatic organisms and can result from industrial discharges, metals contamination, and application of road salts in urban landscapes. The BSID analysis did not find a high concentration of metals in the watershed so high chlorides and consequently high conductivity can most likely be attributed to application of road salts (MDE, 2012b). As there is no specific criterion related to the impact of chlorides, Maryland Department of the Environment (MDE) was not able to identify or impose limits on a specific chloride pollutant in the watershed.

3.2.4 Chesapeake Bay Nutrient and Sediment Impairment

The Chesapeake Bay Program (CBP) has developed the Phase 5 Watershed Model, which, in conjunction with the Estuary Model, is used to determine the sources and reductions of nitrogen, phosphorus, and sediment needed to meet Chesapeake Bay tidal water quality standards. The Phase 5 model was used to develop a Chesapeake Bay-wide TMDL and to assign nutrient and sediment load reductions to individual states and ultimately local jurisdictions based on the segment loads. In Maryland, nutrient and sediment load reductions were assigned on a county basis for achievement by a 2025 timeframe. Table 3-4 lists the pollutant load reduction requirements updated to reflect 2010 reductions for Baltimore County under the Chesapeake Bay TMDL.

Table 3-4: Baltimore County Stormwater Sector Pollutant Load Reductions (EPS, 2012)

TMDL Pollutant	% Pollutant Load Reduction Requirements for Baltimore County 2025
Nitrogen	47.0%
Phosphorus	32.2%

In developing the pollutant reduction strategy in Baltimore County's *Phase II Watershed Implementation Plan*, consideration was also given to the relative delivery ratios for Baltimore County's fourteen 8-digit watersheds and the land use loading rates for urban impervious and urban pervious (EPS, 2012). The Liberty Reservoir watershed has no delivery to the bay due to treatment factors in the reservoir and drinking water withdrawals (EPS, 2012). Therefore any pollutant reduction actions that take place within the watershed receive no credit toward Bay restoration.

3.3 Pollutant Loading Analysis

Pollutant loading analyses are intended to assess the impacts of current and future development on water quality. For the Liberty Reservoir watershed, a pollutant loading analysis was completed based on land-uses in the watershed along with the presence of septic systems within the watershed.

3.3.1 Land-Use Pollutant Loading

Land use analyses have been performed for each of the Maryland designated 8-digit watersheds located entirely or in part within Baltimore County. As part of these analyses, Baltimore County derived watershed-specific pollutant loading rates for nitrogen, phosphorus, and sediment based on the CBP October 2011 Watershed Model. The model derived segment-specific loading rates for urban and non-urban land uses. Pollutant loading rates corresponding to different land use types in the Liberty Reservoir watershed are summarized in Table 3-5.

Table 3-5: Annual Pollutant Loading Rates for Water Resources Element (WRE) Land Use Classifications (lbs./acre/yr.)

WRE Land Cover	Nitrogen Per Acre	Phosphorus Per Acre	Sediment Per Acre
Impervious Urban	17.36	1.51	1,705
Pervious Urban	11.56	0.30	233
Cropland	23.08	1.32	1,157
Pasture	7.97	0.74	285
Livestock (AFO/CAFO)*	162.66	23.92	4,291
Forest	2.79	0.04	71
Water**	10.26	0.61	0
Construction	32.30	5.15	8,800

*AFO/CAFO refers to animal feeding operations and concentrated animal feeding operations

**Nutrient loadings from water were not included in the analysis

As presented in Chapter 2, land use information for the Liberty Reservoir watershed was obtained from Baltimore County and is based on Maryland's Department of Planning (MDP's) 2010 land use/land cover (LU/LC) GIS spatial data. For purposes of the watershed pollutant loading analysis, Baltimore County uses a consolidated version of MDP's LU/LC classifications because loading rates do not differ significantly between certain land use classes (e.g., various forest types). The MDP LU/LC categories present in the Liberty Reservoir watershed and the corresponding Water Resources Element (WRE) land use classes used for the pollutant loading analysis are summarized in Table 3-6.

Table 3-6: Reclassification of MDP LU/LC to Water Resources Element (WRE) Land Use for Liberty Reservoir

MDP LU/LC Classification	WRE Land Cover
11 Low Density Residential	Urban*
12 Medium Density Residential	Urban*
13 High Density Residential	Urban*
14 Commercial	Urban*
15 Industrial	Urban*
16 Institutional	Urban*
18 Open Urban Land	Urban*
21 Cropland	Cropland
22 Pasture	Pasture
23 Orchard	Pasture
41 Deciduous Forest	Forest and Wetlands
42 Evergreen Forest	Forest and Wetlands
43 Mixed Forest	Forest and Wetlands
44 Brush	Forest and Wetlands
50 Water	Water
60 Wetlands	Forest and Wetlands
80 Transportation	Urban*
191 Large Lot Subdivision (Agriculture)	Divided between Urban*, Cropland, Pasture, and Forest
192 Large Lot Subdivision (Forest)	Divided between Urban*, Cropland, Pasture, and Forest
241 Feeding Operations	Livestock (AFO/CAFO)
242 Agricultural Buildings	Livestock (AFO/CAFO)

*These categories were split into pervious urban and impervious urban areas using Baltimore County roads and buildings spatial data.

Total acreages of each WRE land use category were calculated for the Liberty Reservoir watershed. These were multiplied by the corresponding loading rates presented in Table 3-5 yielding annual pollutant loads for total nitrogen, total phosphorus, and total sediment from the watershed. The total annual land use pollutant loadings calculated for the Liberty Reservoir watershed are summarized in Table 3-7.

Table 3-7: Total Annual Pollutant Loads for Nitrogen, Phosphorus, and Sediment for Liberty Reservoir

WRE Land Use	Area (acres)	NITROGEN Loading Rate (lbs./ac)	NITROGEN Load (lbs.)	PHOSPHORUS Loading Rate (lbs./ac)	PHOSPHORUS Load (lbs.)	SEDIMENT Loading Rate (lbs./ac)	SEDIMENT Load (lbs.)
Impervious Urban	709	17.36	12,304	1.51	1,073	1,705	1,208,297
Pervious Urban	3,019	11.56	34,887	0.30	896	233	702,809
Cropland	3,659	23.08	84,423	1.32	4,822	1,157	4,234,501
Pasture	786	7.97	6,258	0.74	578	285	223,955
Livestock (AFO/CAFO)	18	162.66	2,878	23.92	423	4,291	75,920
Forest and Wetlands	7,933	2.79	22,157	0.04	312	71	562,111
Water*	325	-	-	-	-	-	-
Total	***16,449***		***162,906***		***8,104***		***7,007,594***

*Nutrient loadings from Water were not included in the analysis

Note that the pollutant loading rates developed for the water land use category represent atmospheric deposition of nitrogen and phosphorus to water. Because this nutrient delivery system is not addressed in SWAPs, it was not included in the analysis. Also note that MDP land use categories 191-Large lot subdivision (agriculture) and 192-Large lot subdivision (forest) were subdivided into cropland, urban, forest, and pasture land uses based on the percentage breakdown shown in Table 3-8 below and developed by the Baltimore County Environmental Protection and Sustainability (EPS) based on a Geographic Information Systems (GIS) and statistical analysis of various large lot subdivision land use polygons.

Table 3-8: Recommended Loading Group Breakdown by Large Lot Subdivision Type

MDP LU/LC Classification		Proportion of Area by Loading Rate Groups			
		Cropland	Urban	Forest	Pasture
191	Large Lot Subdivision (Agriculture)	14.2%	16.1%	27.6%	42.1%
192	Large Lot Subdivision (Forest)	5.4%	9.6%	78.4%	6.6%

Total annual nitrogen and phosphorus loads estimated for the Liberty Reservoir watershed are 162,906 lbs. TN/year and 8,104 lbs. TP/year, respectively. Total annual sediment loading from land use sources into the Liberty Reservoir watershed is 7,007,594 lbs. sediment/year. Pollutant loadings were also calculated on a subwatershed basis using the same loading rates and land use classification. These estimates will provide baseline pollutant loads before implementation of restoration projects and will allow a better assessment of both progress made to date and further progress needed to meet watershed goals or anticipated TMDLs for urban nonpoint source reduction.

Table 3-9 summarizes the acreages of WRE land use categories by subwatershed in the Liberty Reservoir watershed. The resulting nitrogen, phosphorus, and sediment loads for the 14 subwatersheds are presented in Table 3-10, Table 3-11 and Table 3-12, respectively. These three tables also include annual nitrogen, phosphorus, and sediment loading rates per acre (lbs. /ac/yr.) calculated for each subwatershed.

The tables show that the subwatershed generating the greatest pollutant load is Cliffs Branch. It is important to note that Cliffs Branch has the largest surface area of all subwatersheds (19% of the total watershed) followed by Glen Falls Run (13%) compared to the remaining subwatersheds. In general, the subwatersheds in the Liberty Reservoir are mostly forest and wetland (48%) and cropland (22%). Due to the high percentage of cropland cover the pollutant loadings into surface waters are consequently high. Subwatershed pollutant loadings and rates will be used to prioritize restoration efforts. Total planning level pollutant load estimates will be used to determine necessary reductions to meet watershed goals and any future TMDL reductions.

Table 3-9: Liberty Reservoir Water Resources Element (WRE) Land Use Acreages by Subwatershed

	WRE LAND COVER						
SUBWATERSHED	Impervious Urban	Pervious Urban	Cropland	Pasture	Livestock (AFO/CAFO)	Forest /Wetland	Water
Board-Aspen Run	49	106	434	31	0	139	0
Cliffs Branch	119	432	1,617	213	0	762	0
Glen Falls Run	117	492	318	81	0	1,044	7
Liberty Reservoir-B	33	147	52	4	13	324	64
Keyser Run	81	321	173	98	0	331	1
Liberty Reservoir-E	4	1	69	1	0	171	32
Norris Run	115	503	281	46	0	838	8
Liberty Reservoir-C	12	14	47	58	0	225	33
Timber Run	33	188	71	18	0	623	0
Cooks Branch	25	197	75	43	0	446	0
Liberty Reservoir-F	48	206	248	125	0	1,258	129
Chimney Branch	9	53	60	7	0	310	0
Liberty Reservoir-A	19	77	99	18	4	518	50
Locust Run	43	283	113	42	0	944	2
Total	***709***	***3,019***	***3,659***	***786***	***18***	***7,933***	***325***

Table 3-10: Liberty Reservoir Annual Nitrogen Loads by Subwatershed Based on WRE Land Use (lbs. /yr.)

SUBWATERSHED	Total Area (acres)	WRE LAND COVER: Impervious Urban	Pervious Urban	Cropland	Pasture	Livestock (AFO/CAFO)	Forest /Wetland	Total Nitrogen Load (lbs. /yr.)	Nitrogen Loading Rate (lbs./acre/yr.)
Board-Aspen Run	758	843	1,219	10,014	244	0	389	12,709	16.8
Cliffs Branch	3,142	2,066	4,990	37,317	1,693	0	2,127	48,193	15.3
Glen Falls Run	2,059	2,036	5,690	7,334	644	0	2,915	18,618	9.0
Liberty Reservoir-B	638	576	1,700	1,211	34	2,101	905	6,527	10.2
Keyser Run	1,006	1,413	3,709	3,996	784	47	925	10,873	10.8
Liberty Reservoir-E	280	77	17	1,601	11	0	479	2,185	7.8
Norris Run	1,790	1,994	5,807	6,480	365	0	2,341	16,988	9.5
Liberty Reservoir-C	391	216	163	1,095	464	0	629	2,566	6.6
Timber Run	932	573	2,167	1,629	147	0	1,739	6,254	6.7
Cooks Branch	786	429	2,279	1,735	341	0	1,245	6,028	7.7
Liberty Reservoir-F	2,014	841	2,376	5,715	994	0	3,515	13,441	6.7
Chimney Branch	439	159	611	1,391	56	0	865	3,083	7.0
Liberty Reservoir-A	786	330	890	2,291	144	730	1,447	5,832	7.4
Locust Run	1,428	750	3,269	2,615	337	0	2,638	9,609	6.7
Total	***16,449***	***12,304***	***34,887***	***84,423***	***6,258***	***2,878***	***22,157***	***162,906***	***9.9***

Table 3-11: Liberty Reservoir Annual Total Phosphorus (TP) Loads by Subwatershed Based on WRE Land Use (lbs. /yr.)

SUBWATERSHED	Total Area (acres)	WRE LAND COVER						Total Phosphorus Load (lbs. /yr.)	Phosphorus Loading Rate (lbs./acre/yr.)
		Impervious Urban	Pervious Urban	Cropland	Pasture	Livestock (AFO/CAFO)	Forest /Wetland		
Board-Aspen Run	758	73	31	572	23	0	5	705	0.93
Cliffs Branch	3,142	180	128	2,131	156	0	30	2,626	0.84
Glen Falls Run	2,059	178	146	419	59	0	41	843	0.41
Liberty Reservoir-B	638	50	44	69	3	309	13	488	0.77
Keyser Run	1,006	123	95	228	72	7	13	539	0.54
Liberty Reservoir-E	280	7	0	91	1	0	7	106	0.38
Norris Run	1,790	174	149	370	34	0	33	760	0.42
Liberty Reservoir-C	391	19	4	63	43	0	9	137	0.35
Timber Run	932	50	56	93	14	0	24	237	0.25
Cooks Branch	786	37	59	99	31	0	18	244	0.31
Liberty Reservoir-F	2,014	73	61	326	92	0	49	602	0.30
Chimney Branch	439	14	16	79	5	0	12	126	0.29
Liberty Reservoir-A	786	29	23	131	13	107	20	324	0.41
Locust Run	1,428	65	84	149	31	0	37	367	0.26
Total	***16,449***	***1,073***	***896***	***4,822***	***578***	***423***	***312***	***8,104***	***0.49***

Table 3-12: Liberty Reservoir Annual Sediment Loads by Subwatershed Based on WRE Land Use (lbs. /yr.)

		WRE LAND COVER							
SUBWATERSHED	Total Area (acres)	Impervious Urban	Pervious Urban	Cropland	Pasture	Livestock (AFO/CAFO)	Forest /Wetland	Total Sediment Load (lbs. /yr.)	Sediment Loading Rate (lbs./acre/yr.)
Board-Aspen Run	758	82,749	24,566	502,299	8,736	0	9,857	628,208	829.0
Cliffs Branch	3,142	202,856	100,531	1,871,732	60,600	0	53,971	2,289,689	728.7
Glen Falls Run	2,059	199,930	114,628	367,841	23,052	0	73,941	779,393	378.5
Liberty Reservoir-B	638	56,613	34,238	60,734	1,225	55,427	22,957	231,194	362.6
Keyser Run	1,006	138,768	74,722	200,413	28,057	1,231	23,461	466,652	463.7
Liberty Reservoir-E	280	7,575	339	80,300	409	0	12,142	100,766	359.9
Norris Run	1,790	195,873	116,986	325,035	13,061	0	59,399	710,354	396.8
Liberty Reservoir-C	391	21,167	3,274	54,907	16,593	0	15,966	111,908	286.5
Timber Run	932	56,276	43,648	81,698	5,255	0	44,122	231,000	247.8
Cooks Branch	786	42,143	45,915	87,004	12,196	0	31,573	218,830	278.6
Liberty Reservoir-F	2,014	82,618	47,856	286,677	35,569	0	89,164	541,884	269.1
Chimney Branch	439	15,657	12,318	69,788	1,992	0	21,936	121,691	277.2
Liberty Reservoir-A	786	32,393	17,937	114,908	5,143	19,262	36,707	226,350	287.9
Locust Run	1,428	73,680	65,851	131,166	12,064	0	66,916	349,677	244.9
Total	***16,449***	***1,208,297***	***702,809***	***4,234,501***	***223,955***	***75,920***	***562,111***	***7,007,594***	***426.0***

3.3.2 Septic Pollutant Loading

The majority of the Liberty Reservoir watershed relies on septic systems for waste treatment; public sewer systems only cover the outer edge of the south-east boundary of the watershed. Septic systems are designed so that waste goes into a tank, enabling solids to settle at the bottom and liquids to flow through a septic field. While some phosphorus can become soluble in septic systems, it is assumed that only nitrogen is distributed to the septic field for pollutant loading calculations (CBP, 2009).

The nitrogen load that passes into the septic field, through the soil, reaches the stream system through groundwater. Septic systems are classified based on their location in the watershed, specifically their proximity to streams. Loading rates are 10.28 lbs. nitrogen/year if the system is within 1,000 feet of a stream and 6.17 lbs. nitrogen/year if the stream is located further than 1,000 feet of a stream. In the Liberty Reservoir watershed, there are no septic systems located within the Chesapeake Bay Critical Area.

As shown in Table 3-13, Liberty Reservoir has a high number of septic systems due to the rural nature of the watershed with the majority of the area located outside the Urban/Rural Demarcation Line (URDL) (see Section 2.3.6.3). The total estimated annual nitrogen load due to septic systems was calculated as 23,336 lbs. /yr. and is broken down by subwatershed in Table 3-13.

Table 3-13: Total Septic Systems and Population by Subwatershed

		# of Septic Systems		Nitrogen Load (lb. N/year)		
Subwatershed	**Total # of Septic Systems**	**<1000' from stream**	**>1000' from stream**	**<1000' from stream**	**>1000' from stream**	**Total Nitrogen Load**
Board-Aspen Run	143	137	6	1,408	37	1,445
Cliffs Branch	397	385	12	3,958	74	4,032
Glen Falls Run	330	330	0	3,392	0	3,392
Liberty Reservoir-B	73	73	0	750	0	750
Keyser Run	166	166	0	1,706	0	1,706
Liberty Reservoir-E	6	6	0	62	0	62
Norris Run	334	324	10	3,331	62	3,392
Liberty Reservoir-C	32	32	0	329	0	329
Timber Run	146	140	6	1,439	37	1,476
Cooks Branch	151	151	0	1,552	0	1,552
Liberty Reservoir-F	168	168	0	1,727	0	1,727
Chimney Branch	29	29	0	298	0	298
Liberty Reservoir-A	65	65	0	668	0	668
Locust Run	246	240	6	2,467	37	2,504
Total	***2,286***	***2,246***	***40***	***23,089***	***247***	***23,336***

3.3.3 Total Pollutant Loading

The total estimated pollutant loads based on land use and septic systems within the entire Liberty Reservoir watershed are summarized in Table 3-14.

Table 3-14: Total Annual Pollutant Loading for Liberty Reservoir

WRE Land Use	Total Nitrogen Load (lb./year)	Total Phosphorus Load (lb./year)	Total Sediment Load (lb./year)
Impervious Urban	12,304	1,073	1,208,297
Pervious Urban	34,887	896	702,809
Cropland	84,423	4,822	4,234,501
Pasture	6,258	578	223,955
Livestock (AFO/CAFO)	2,878	423	75,920
Forest and Wetlands	22,157	312	562,111
Water	-	-	-
Septic Systems	23,336	-	-
Total	***186,241***	***8,104***	***7,007,594***

3.4 Water Quality Monitoring Data

Baltimore County and Maryland Department of Natural Resources (DNR) have conducted chemical, physical, and biological monitoring for the Liberty Reservoir watershed through various programs.

3.4.1 Flow Monitoring

There are no United States Geological Survey (USGS) stream gage stations in the Baltimore County portion of the Liberty Reservoir Watershed.

3.4.2 Baltimore Countywide Monitoring

Baltimore County conducts several water quality monitoring programs across the county. The following subsections provide details on the chemical, biological, and bacterial monitoring that is currently in place. There is no geomorphologic monitoring for Liberty Reservoir.

3.4.2.1 Trend Chemical Monitoring

Baltimore County's Trend Chemical Monitoring Program observes ambient chemical conditions and determines trends in chemical concentrations and pollutant loads over time. This data is used to determine areas to target restoration, assess the impact of implemented restoration activities, and determine the amount of progress made towards meeting TMDLs and other restoration goals. The program was initiated in January 2011 and replaced Baltimore County's previous Baseflow Monitoring program. Sites are visited on the same day, once per month. In the Liberty Reservoir watershed, there are a total of three monitoring sites located in the Cliffs Branch, Glen Falls Run, and Norris Run subwatersheds as shown in Figure 3-1.

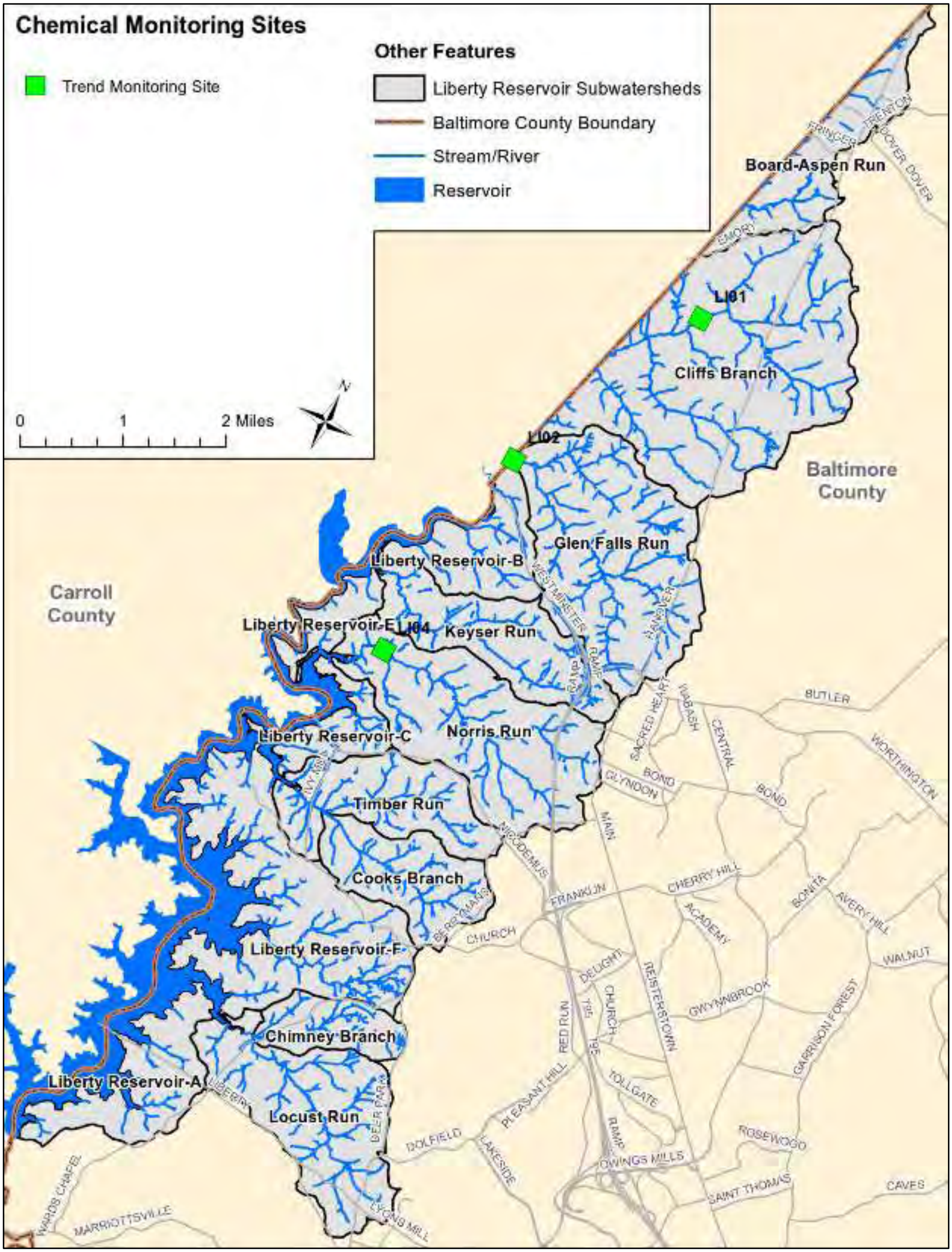

Figure 3-1: Chemical Monitoring Sites in Liberty Reservoir

32 quality parameters were measured in trend monitoring including total suspended solids (TSS), total solids (TS), total kjeldahl nitrogen (TKN), nitrate-nitrite, total phosphorus (TP), chloride (Cl^-), sodium (Na), biochemical oxygen demand (BOD), chemical oxygen demand (COD), hardness, magnesium, and calcium as well as water temperature and pH determined in situ. If water quality parameters registered below the equipment detection limit, they were given a value of half the detection limit.

Of particular importance were measurements for total suspended solids (TSS), nutrients (nitrogen and phosphorus), chlorides, and temperature due to 303(d) listings and TMDL as well as sodium due to the downstream impoundment's use as a water supply:

- Suspended Solids: Excessive suspended solids can adversely impact aquatic life as it affects the light available for photosynthesis by plants and visual capability of aquatic life. Decreased light can lead to a decrease in algae communities that may limit food supplies and reduce growth rates of invertebrate and fish communities. Suspended solids can inhibit the hunting capability of visual fish predators and cause gill damage. Excessive sediment can also negatively affect habitat structure, through the burial of space between the gravel in the stream bottom (called embeddedness). Embeddedness can kill incubating fish eggs/larvae and benthic macroinvertebrates and can trap bacteria and organics on the stream bottom causing oxygen depletion. Over the long term, excessive sediment can also reduce the storage volume available in the reservoir.
- Nutrients: Over-enrichment of water bodies by excessive nutrient input can cause excessive growth of aquatic plants (algal blooms) and bacterial consumption of dissolved oxygen when the plants decompose. This can lead to significant reductions in water quality as well as abundance and diversity of aquatic life communities.
- Temperature: Water temperature is the single most important factor that limits the geographic distribution of aquatic life. The fish may be found in waters with temperature ranges from 0 – 24°C; however, the temperature should not exceed 20°C (the water quality criteria for Use III Waters) for an optimal environment.
- Chlorides and Sodium: Natural stream systems can also be impaired by urban land use and its effects such as an increase in dissolved substances (including chloride and sodium) in runoff. Chlorides come from a variety of sources including industrial discharges, metals contamination, and road salt application. The most likely source of chlorides entering the Liberty Reservoir is from the storage and application of road salt (MDE, 2012b). Road salt has also been identified as a major contributor to sodium levels in the watershed and reservoir (ACEQ, 2009). Increased chloride and sodium levels are associated with degraded biological conditions by inversely impacting water quality, soil chemistry, and aquatic health.

Stream ratings based on total nitrogen concentration established using data adapted from DNR, and loading coefficients reported by Frink are shown in Table 3-15 (Frink, 1991). Ratings for total phosphorus were developed by evaluating non-tidal phosphorus data from the CBP, also shown in Table 3-15 (Belval & Sprague, 1999).

Table 3-15: Stream Ratings by Nutrient Concentration

Rating	Total Nitrogen (TN)	Total Phosphorus (TP)
Baseline	0.0 – 1.0	< 0.05
Slightly elevated	1.0 – 2.0	0.05 - 0.075
Moderate	2.0 – 3.0	0.075 – 0.10
High	3.0 – 5.0	0.10 – 0.20
Excessive	> 5.0	> 0.20

Three trend monitoring sites are located within the Liberty Reservoir area. The trend monitoring data for 2011 to 2013 are summarized in Table 3-16.

Table 3-16: Liberty Reservoir Trend Monitoring Summary by Site

Parameter		Site LI01	Site LI02	Site LI04
Total Suspended Solids (TSS) (mg/L)	No. Samples	36	36	36
	Max	454	450	552
	Min	0.50	0.00	0.50
	Median	0.50	0.50	0.50
	Mean	**17.67**	**16.28**	**18.10**
	Std. Dev	76.90	74.78	91.77
Total Nitrogen (mg/L)	No. Samples	27	27	27
	Max	6.57	20.37	3.70
	Min	3.29	0.41	1.19
	Median	5.37	2.17	1.97
	Mean	**5.08**	**2.69**	**2.15**
	Std. Dev	1.14	3.59	0.65
Total Phosphorus (mg/L)	No. Samples	34	34	34
	Max	1.11	0.57	0.85
	Min	0.03	0.03	0.03
	Median	0.03	0.03	0.03
	Mean	**0.08**	**0.04**	**0.06**
	Std. Dev	0.19	0.09	0.15
Temperature (°C)	No. Samples	36	36	36
	Max	22.40	22.00	22.30
	Min	0.10	0.40	0.83
	Median	12.00	12.10	12.55
	Mean	**12.49**	**12.01**	**12.33**
	Std. Dev	6.34	6.72	6.52
Chloride (mg/L)	No. Samples	28	28	28
	Max	45.48	228.83	402.84
	Min	6.05	15.87	15.07
	Median	32.92	49.04	57.24
	Mean	**33.08**	**57.81**	**70.47**
	Std. Dev	7.42	35.98	66.26
Sodium (mg/L)	No. Samples	36	36	36
	Max	38.00	167.70	252.20
	Min	1.80	5.10	5.60
	Median	12.10	18.80	18.85
	Mean	**13.13**	**25.43**	**26.59**
	Std. Dev	5.90	27.93	39.65

Suspended solids concentrations may not reflect elevated concentrations which are typically during storm events. Average total nitrogen concentrations were rated as “Excessive” at Site LI01 and “Moderate” at Sites LI02 and LI04. The highest concentrations were observed at site LI02 in Glen Falls Run. TP averages were rated as “baseline” for Site LI02; “Slightly elevated” for Site LI04; and “Moderate” for Site LI01 at

Cliffs Branch. Besides TSS, TP, and TN, temperature, chlorides, and sodium are water quality parameters measured in trend monitoring that were further evaluated.

The water quality criterion for maximum temperature in Use I Waters is 32°C and in Use III Waters is 20°C or the ambient temperature of the surface water; however, a thermal barrier that adversely affects aquatic life may not be established (COMAR, 2014b). Locust Run, Keyser Run, Timber Run, and Glen Falls Run were listed as impaired for temperature in 2014. The three sampling sites in Liberty Reservoir surpass the maximum temperature of 20°C between 17-19% of the times sampled. The temperature exceedance occurred during the months of June to September. The maximum temperature recorded at any site was 22.4°C in August at Site LI01.

Natural stream systems can also be impaired due to the usage of road salt in the winters. Road salt (NaCl) enters the stream system as roadway runoff and dissolves in water into sodium and chloride ions, inversely impacting water quality, soil chemistry, and aquatic health. According to the Baltimore County Advisory Commission on Environmental Quality, Baltimore County and the State apply more road salts than other jurisdictions at a rate of approximately 1.2 tons of salt per lane mile per storm and 3.2 tons of salt per lane mile per storm, respectively (ACEQ, 2009). While there is currently no state water quality criterion for chlorides, MDE has recommended a future water quality standard be implemented (MDE, 2013). The USEPA's recommended water quality criterion for aquatic life for chloride is 860 mg/L for acute exposure and 230 mg/L for chronic exposure (USEPA, 2014). Similarly, there is no water quality criteria established for sodium; however, the USEPA warns that people under strict sodium diets not consume water with sodium concentrations exceeding 20 mg/L (USEPA, 2003). While the current monitoring indicated chloride levels below the United States Environmental Protection Agency's (USEPA's) recommended limits, mean sodium levels were above 20 mg/L for two of the three sampling sites, Sites LI02 and LI04. Since 1973, a nearly three-fold increase in sodium levels has been observed in the treated water coming from the Liberty Reservoir and treated at the Ashburton plant (ACEQ, 2009).

Biological Monitoring

Biological monitoring for Liberty Reservoir has been conducted by Baltimore County since 2003 following the Maryland Biological Stream Survey (MBSS) probabilistic monitoring methods to assess ecological health in local streams. In odd-numbered years (except 2009), macro-invertebrate samples were taken during the spring index period and a Benthic Index of Biotic Integrity (BIBI) score was calculated. The BIBI scores were grouped and given a condition rating: "Very Poor" (1.00 – 1.99), "Poor" (2.00 – 2.99), "Fair" (3.00 – 3.99), and "Good" (4.00 – 5.00) (EPS, 2013). Table 3-17 provides the distribution of BIBI scores calculated for Liberty Reservoir watershed between 2003 and 2011. A visual reference of the distribution of BIBI scores across all monitoring years is shown in Figure 3-2.

Table 3-17: Historical BIBI Scores in the Liberty Reservoir Watershed (EPS, 2013)

Year	# of Samples	Very Poor (1.00 - 1.99)	Poor (2.00 - 2.99)	Fair (3.00 - 3.99)	Good (4.00 - 4.99)
2003	10	10%	50%	30%	10%
2005	22	5%	32%	41%	23%
2007	20	0%	0%	30%	70%
2009	15	0%	0%	0%	0%
2011	10	0%	10%	70%	20%

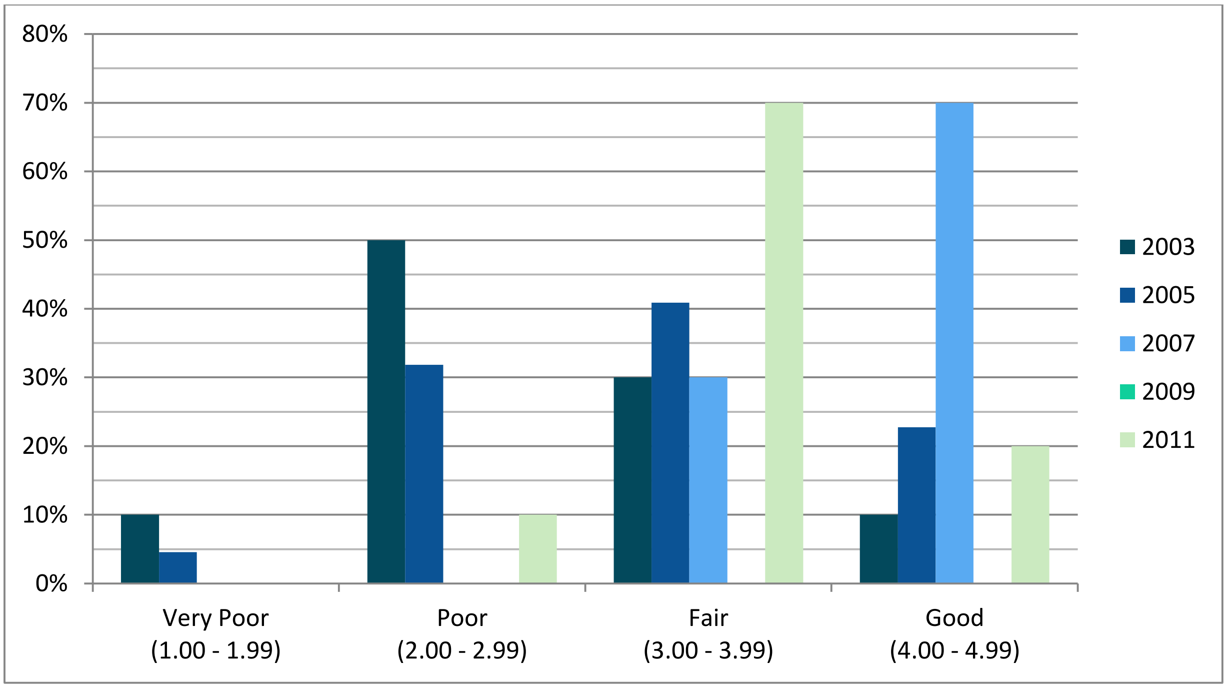

Figure 3-2: Distribution of BIBI Scores in the Liberty Reservoir Watershed over Time

Since monitoring began in 2003, the BIBI scores have shown signs of improvement. In 2003, 60% of the sites were rated either "Very Poor" or "Poor" and only 10% were rated "Good". In the most recent samplings of 2011, 70% of the sites were rated "Fair" and 20% were rated "Good". The location of sampling sites within the Liberty Reservoir watershed and their corresponding condition are shown in Figure 3-3.

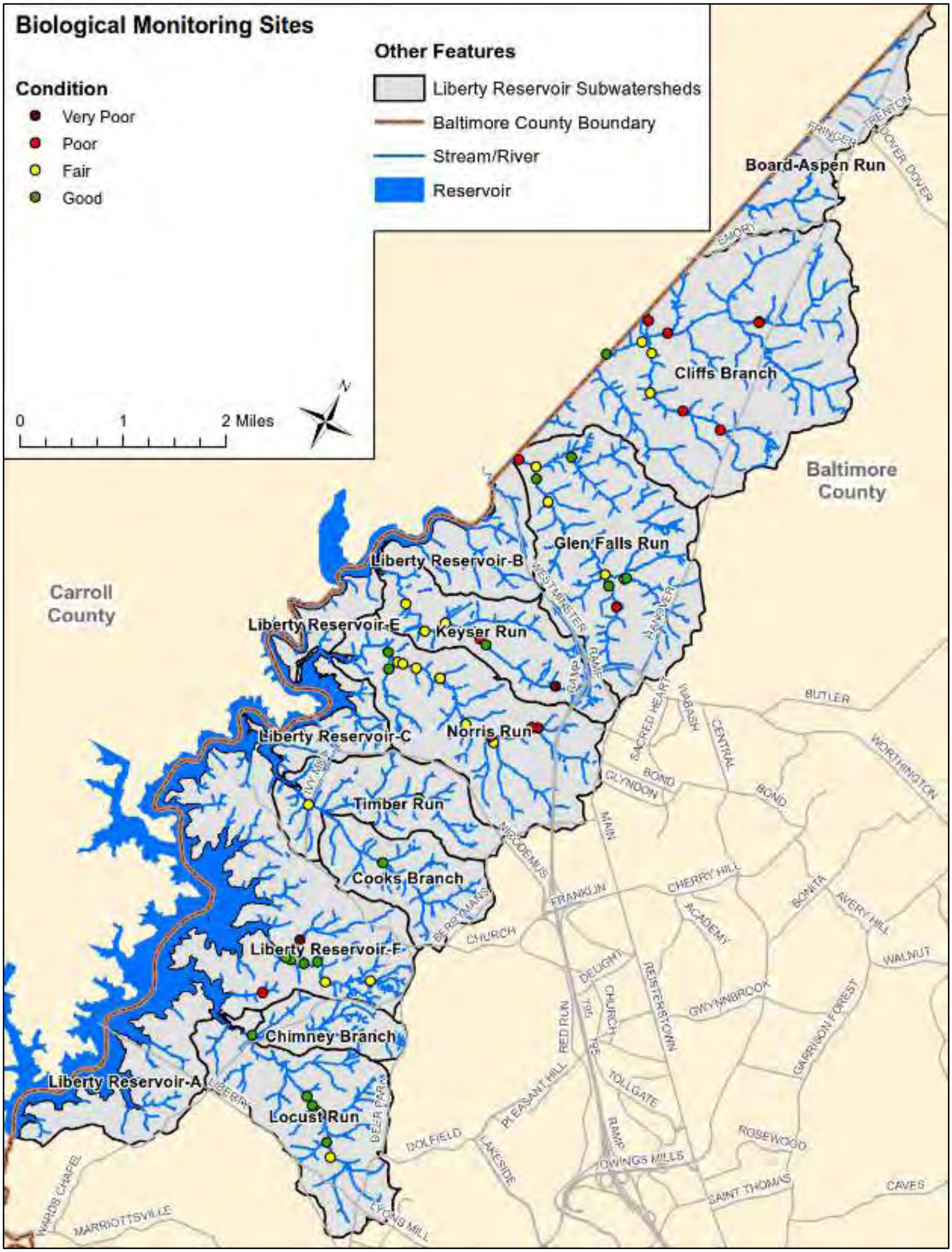

Figure 3-3: Biological Monitoring Sites from 2004-2012 in Liberty Reservoir

3.4.2.2 *Bacterial Monitoring*

In addition to chemical and biological monitoring, Baltimore County conducts Bacteria Trend Monitoring in response to the development of bacteria TMDLs. Beginning in June of 2010, Baltimore County EPS has coordinated with the Baltimore City Surface Water Management Division to monitor bacteria trend levels at 35 sites throughout the county and are proposing 19 new locations in Liberty Reservoir. Currently, all five active monitoring sites within the overall Liberty Reservoir watershed are within Carroll County. Table 3-18 shows the percentage of samples at each site in Carroll County that were above the Single Sample Maximum Allowable Density for Infrequent Full Body Contact Recreation of 576 MPN/100mL (COMAR, 2014b). Based on the percentage of samples that exceeded the limit, each site was rated as Good (0-25%), Fair (26-50%), Poor (51-75%), or Very Poor (76-100%). Figure 3-4 shows the locations of current bacteria monitoring sites and proposed future monitoring sites.

Table 3-18: Annual *E. coli* Concentrations and Ratings for the Liberty Reservoir Watershed (EPS, 2013)

Station ID	Total # Samples	Geometric Mean (MPN/100ml)	% Samples Exceeded Limit (576 MPN/100ml)	Rating
LIB-1	10	87.45	0%	Good
LIB-2	11	79.05	9%	Good
LIB-3	12	331.44	42%	Fair
LIB-4	11	90.74	0%	Good
LIB-5	11	157.44	18%	Good

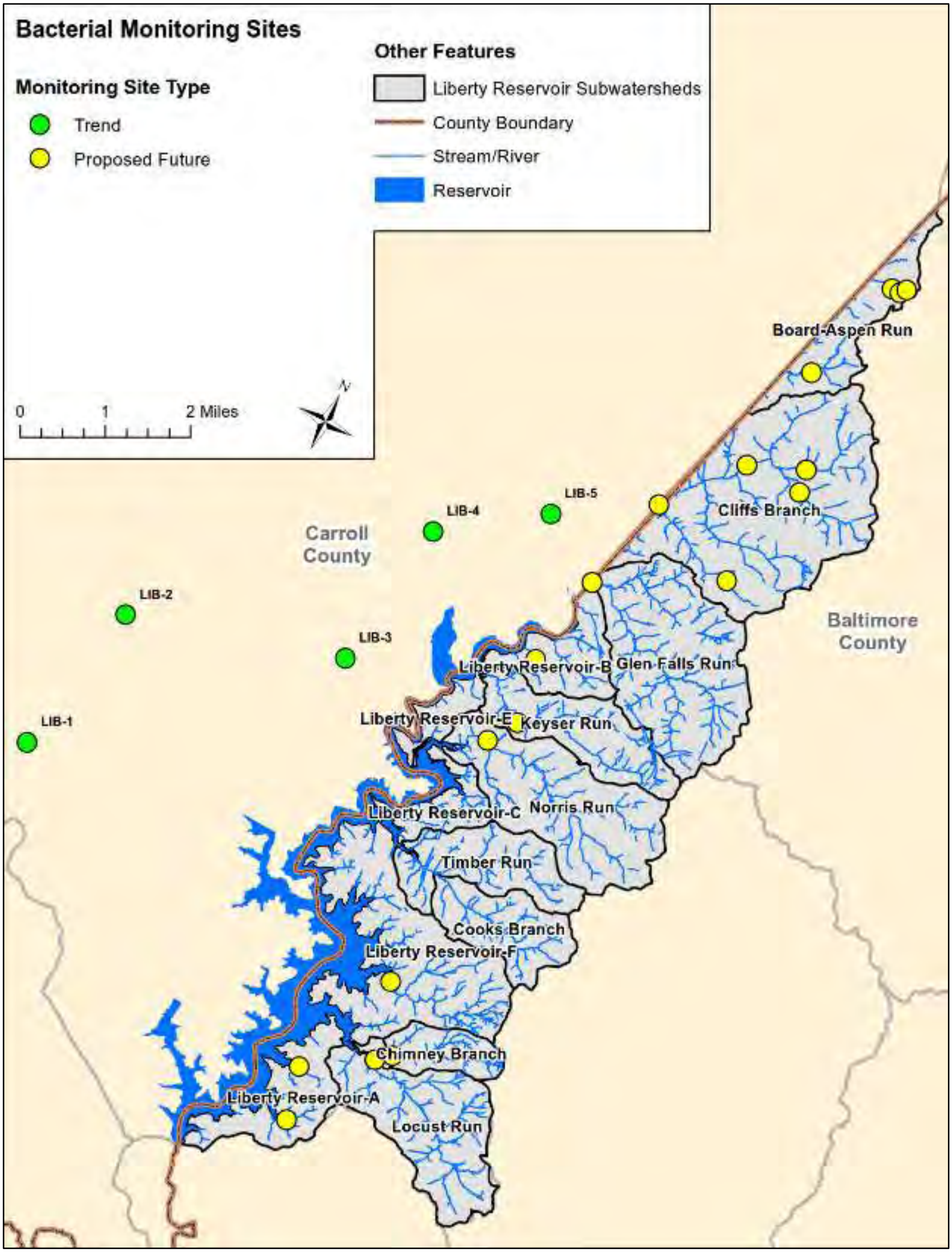

Figure 3-4: Bacteria Monitoring Sites in the Liberty Reservoir Watershed

3.4.3 Illicit Discharge and Elimination Data

Baltimore County monitors illicit discharges from its storm sewer system through a program of routine outfall screenings. The program consists of three parts:

1. A quantitative analysis of the effluent that includes measuring the effluent flow rate, temperature and pH, and field testing for parts per million (ppm) of chlorine, phenols, copper, and ammonia using a specially configured LaMotte NPDES test kit;
1. A qualitative assessment of the effluent, outfall structure, and receiving channel noting conditions such as water color, odor, vegetative condition, sedimentation, erosion, damage, etc.; and
2. A visual inspection of each outfall that identifies any structural damage.

There is 1 major outfall (>3 ft.) and 30 minor outfalls (<3 ft.) documented through spatial data by Baltimore County EPS in the Liberty Reservoir watershed. The County has an outfall prioritization system based on data from the outfall screenings. The prioritization system allows for a more streamlined approach in selecting outfalls to screen and provides a more efficient use of manpower.

Under the outfall prioritization system, outfalls that have not been screened at least twice are not prioritized. Prioritized outfalls, those screened two or more times, are assigned one of the following priority ratings:

- Priority 1 (Critical): Outfalls with major problems that require immediate correction and/or close monitoring, or outfalls with recurring problems. These outfalls are sampled four times each year.
- Priority 2 (High): Outfalls with moderate to minor problems that have the potential to become severe. These outfalls are sampled once per year.
- Priority 3 (Low): Outfalls with minor or no problems that do not require close monitoring. These outfalls are sampled on a 10-year cycle.
- Priority 0 (Not prioritized): Outfalls with insufficient data to determine a priority rating. This may be due to inaccessibility, or if there has been an insufficient number of screenings. Major outfalls need three visits and minor outfalls need one visit before being prioritized.

The major outfall documented in the Liberty Reservoir watershed has a Priority 2 rating, and one minor outfall has a Priority 3 rating. Both outfalls are located in the Norris Run subwatershed (see Figure 2-16). Table 3-19 summarizes the priority rating for these outfalls.

Table 3-19: Baltimore County Storm Drain Outfall Prioritization Results for Liberty Reservoir

	OUTFALL PRIORITY RATING				
Subwatershed	Priority 1	Priority 2	Priority 3	Priority 0	Total
Norris Run	0	1	1	0	0

3.5 Additional Studies

Various reports and studies have been conducted by state, county, and municipal agencies pertaining to Liberty Reservoir and the watershed's water quality. The reports are summarized in the sections below.

3.5.1 Road Salt Management

The Maryland State Legislature passed two bills in 2010 requiring the establishment of a Statewide Salt Management Plan; the Maryland State Highway Administration (SHA) in conjunction with MDE developed the document to minimize adverse impacts of road salt runoff in the state of Maryland. The objective of the Statewide Salt Management Plan is to provide a framework for highway agencies to deliver safe, efficient roadways during winter storms cost effectively while also acknowledging their obligation to do so in the most environmentally sensitive manner practicable (SHA, 2014). The report highlights the importance of providing public safety and mobility during winter storm events, but highlights the importance of proper storage, handling, and distribution of salt and the significance of alternative de-icing methods to ensure minimal negative environmental impacts. The severity and duration of winter storms dictates the quantity of salt required to maintain levels of service along roadways; currently, salt is the primary snow and ice control material due to its low cost.

Over salting can have significant environmental impacts. A report conducted by DNR directly links road salts to increasing levels of sodium in fresh water sources (DNR, 2013). Increased sodium levels result in poor aquatic habitat and a decrease in populations of fish, amphibians, and other macro invertebrates. Currently, there are no water quality criteria for chloride or sodium in Maryland.

3.5.2 Reservoir Management

The Reservoir Watershed Management Agreement was signed in 2005 to continue the review of problems and actions affecting the three Baltimore County water-supply reservoir watersheds and provide recommendations to protect the three reservoirs (RWPC, 2005). The agreement is signed by multiple government agencies including Baltimore County, Baltimore City, Carroll County, Maryland Department of the Environment, Maryland Department of Agriculture, Baltimore and Carroll counties Soil Conversation District, Reservoir Watershed Protection Committee (RWPC) and Baltimore Metropolitan Council (BMC). The Liberty Reservoir is one of the three water-supply reservoirs in Baltimore County. Based on capacity in 2001, Liberty Reservoir has lost 1.28 billion gallons of storage capacity since its inception in 1954 (RWPC, 2005).

The Action Strategy for the Reservoir Watersheds consists of actions to be completed by various entities in order to protect and maintain the quality of water draining to the three reservoirs. These actions include monitoring the reservoirs and major tributaries, watershed modeling, issuing discharge permits (NPDES), promoting agricultural Best Management Practices (BMPs), continuing the implementation of stormwater management regulations, administering sewer and septic regulations and inspections, aiding urban nutrient reductions, and overall land management through conservation and strategic development (BRWMP, 2005).

A progress report regarding the Action Strategy was published in 2009 by the Baltimore Metropolitan Council summarizing the 93 original "actions" recommended and focuses on the status of these commitments (BMC, 2009). Many of the efforts were found to be ongoing. One key action pertaining to the Liberty Reservoir watershed was the commitment to seek funding to study the contribution of nutrients from septic systems; the majority of the watershed is on septic systems and further studies need to be completed to accurately estimate the pollutant loads. Overall, the majority of the actions are being performed although no further progress reports have been published.

3.5.3 Baltimore County Master Plan

The Baltimore County Master Plan is a guidance document for future development within Baltimore County. The goal of the Master Plan is to protect the environment, preserve agriculture, and ensure safe and attractive places to live and work (DP, 2010). The plan aims to focus development and redevelopment within the URDL to direct growth away from sensitive ecological features. The vast majority of proposed land use within the document for the Liberty Reservoir watershed consists of Natural Zones (T-1: natural condition), Rural Zones (T-2: sparsely settled lands in an open or cultivated state), and small amounts of Rural Residential Zones (T-2 R: large lot single-family detached housing) in the south. The report also emphasizes the importance of resource conservation with the county's current goal for land preservation of at least 80,000 acres of land to protect agriculture and natural resources.

3.5.4 Maryland Brook Trout Management Plan

Brook trout are the only trout in Maryland for which a Fisheries Management Plan was written due to their valuable standing as Maryland's only native freshwater trout species and concerns of their current status (DNR, 2006). Brook trout require high quality waters for survival and cannot typically survive in waters where temperatures exceed 68°F. The Fisheries Management Plan aims to restore and maintain healthy brook trout populations in Maryland's freshwater streams and provide long-term social and economic benefits from a recreational fishery. In Maryland, the top five reasons for loss and degradation of brook trout populations are 1) high water temperatures, 2) agriculture, 3) urbanization, 4) exotics (brown trout), and 5) poor riparian habitat.

As of fall 2005, there were three subwatersheds in Liberty Reservoir that had known sustaining brook trout populations (Cooks Branch, Timber Run, and Norris Run) (DNR, 2006). The brook trout population in these subwatersheds is confined to approximately 3.5 miles of stream. Brook trout extirpation is likely when human land use exceeds 18% of a watershed. Brook trout typically remains an *intact* population when human land use (any human-caused change from pre-settlement habitat type) is less than 10% (DNR, 2006). An *intact* population means that more than 50% of all native habitats in the subwatershed support self-sustaining brook trout populations. While the management plan includes recommendations to restore native brook trout populations in Maryland, these efforts will likely be focused in special trout management areas, of which the North Branch Patapsco (including Liberty Reservoir) is not included.

3.5.5 White-tailed Deer Management

Overabundant deer populations have a negative impact on forest health as deer eat understory and ground vegetation limiting the regenerative ability of the forests. This limits the stormwater benefits attributed to a healthy forest system such as slowed surface water flow, prevention of soil erosion, ground water filtration, and nutrient reduction. The lack of native understory vegetation also eliminates food and habitat for other wildlife, reducing biodiversity, and can increase the presence of invasive plants. While the recommended deer density to prevent forest degradation is approximately 15 to 20 deer per square mile, the average deer density in Baltimore County is 95 deer per square mile, according to a 2009 study (EPS, 2014). A reported 6,336 deer were harvested in Baltimore County during the 2013-2014 hunting season; of that number, 98 were harvested from the Liberty Reservoir Watershed (DNR, 2014b).

3.5.5.1 County White-tailed Deer Management

Deer herd management in Baltimore County began with the City of Baltimore's efforts to control deer herds at the reservoirs, Liberty, Prettyboy, and Loch Raven, through public bow hunting and deer cooperator approaches. Public hunting has been allowed at Liberty Reservoir for several decades. During the 2011 to 2012 season, a total of 324 deer were culled at Liberty Reservoir through the deer herd management program. Forward-Looking Infra-Red (FLIR) surveys are used to survey deer populations and to estimate additional reductions necessary to reduce deer pressure on the forest (EPS, 2014).

3.5.5.2 Maryland White-tailed Deer Plan 2009-2018

A white-tailed deer management plan was created by the Maryland Department of Natural Resources (DNR) to document the history and current status of white-tailed deer in Maryland, describe the responsibilities of the DNR deer management program, and serve as a strategic plan for deer management through 2018. The plan provides a myriad of strategic management options for statewide use. DNR has increased assistance to public land managers to develop deer hunting programs outside of the regular deer hunting season framework to address population issues. DNR also employs deer biologists to work with communities and derive the best management strategy to meet their local interests and needs (DNR, 2009).

In the state of Maryland, deer hunters remove approximately 100,000 deer a year at little or no financial burden to the general public. Additionally, Deer Management Permits (DMPs) are available for producers (i.e. farmers, arborists, etc.) in situations where the deer hunting season does not adequately regulate the population. Another regulation program is the Maryland Deer Cooperator Program that certifies private individuals to lethally remove deer for a profit from areas where hunting is not feasible; the cost for deer removal ranges from $150 to $450 per deer. DNR also authorizes managed deer hunting programs for hunts primarily on county and federally owned lands with favorable results. Finally, contraception has been experimentally tested in the white deer population control with mixed results. The State of Maryland has also created the venison donation program to provide a way for hunters to make use of more deer than they normally would in a given year, encouraging more deer culling (DNR, 2009).

3.5.6 Liberty Reservoir Watershed Action Strategy within Carroll County, MD

In March, 2003, Carroll County produced a Watershed Restoration Action Strategy (WRAS) "designed to maintain and enhance the water quality of streams draining to Liberty Reservoir" (Carroll County, 2003). To accomplish this objective, the study developed a watershed characterization for the Carroll County portion of the Liberty Reservoir watershed, conducted stream corridor assessments in three selected subwatersheds, developed action strategies to address water quality degradation and impairment, and identified opportunities to work with stakeholders to implement the WRAS.

The land uses of Carroll County's portion of the Liberty Reservoir watershed are predominately classified in the WRAS as agricultural (60%) or residential (20%) with the remaining areas split between commercial/industrial, publicly owned, and "other." Stream corridor assessments (SCAs) were conducted within the Middle Run, Snowdens Run, and West Branch subwatersheds. The three most common impairments identified during the SCAs were erosion sites, pipe outfalls, and inadequate buffers. A subwatershed map of the Carroll County portion of the Liberty reservoir watershed can be seen in Figure 3-5.

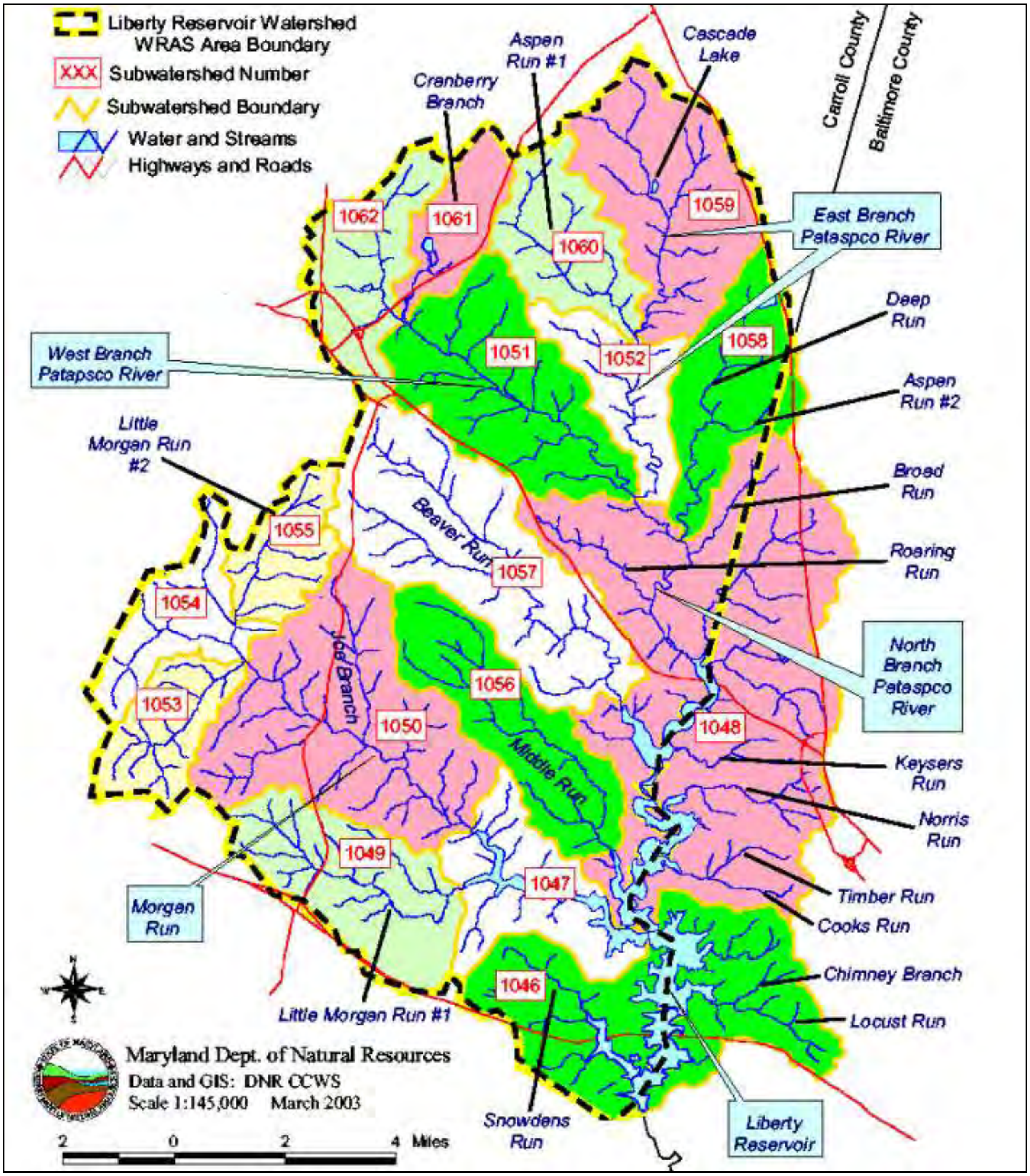

Figure 3-5: Subwatershed Map of the Carroll County Portion of the Liberty Reservoir Watershed (Carroll County, 2003)

The action strategies developed in the WRAS are summarized as follows:

1. Nutrient Source Tracking Strategy – Further investigation of the sources of nutrient pollution was recommended to target specific areas for restoration of protection.
2. Agriculture BMP Targeting Strategy – Using maps of agricultural BMPs developed for the WRAS, the Carroll County Soil Conservation District will determine areas where further work needs to be accomplished in targeted watersheds.
3. Stormwater Retrofit and Storm Drain Repair Strategy – The intent of this action item is to retrofit existing SWM facilities as well as provide repairs to storm drains that are degrading water quality. Working with the Bureau of Road Operations, which performs or contracts out repairs, Carroll County will compare areas where impairments related to pipe outfalls and SWM facilities were identified during SCAs to areas where citizen complaints have been received to prioritize repair work. In high priority subwatersheds, designers of new development will be directed to retrofit existing storm drains.
4. Stream Buffer Planting Strategy – The County will coordinate with the Carroll County Soil Conservation District and Friends of Carroll County Streams to seek opportunities for stream buffer plantings in areas where inadequate stream buffer impairments were identified in the SCAs.
5. Database Update Strategy – Carroll County will keep databases important to future watershed assessments updated to help "monitor the progress of the implementation of BMPs, determine the status of the number and types of protective measures (e.g., conservation easements) implemented, and show up-to-date possible causes of degradation to the resource" (Carroll County, 2003).
6. Establish Watershed Advisory Committees – The committees will be responsible for implementing action strategies identified in the WRAS as well as future assessments and evaluations.
7. County Program Coordination Strategy – This action is intended to coordinate the various development review agencies and processes within the county to provided more robust natural resource protection.

3.6 Stream Corridor Assessments

Stream Corridor Assessments (SCAs) were conducted for selected streams in the Liberty Reservoir watershed. The subwatersheds selected for SCAs include Cliffs Branch, Keyser Run, and Norris Run. The assessments were conducted based on Maryland DNR's SCA Survey Protocols, which were developed as a tool for environmental managers to quickly identify environmental problems within a watershed's stream network (Yetman, 2001). This methodology presents a rapid field survey, rather than a detailed scientific assessment, to better target monitoring, management, and conservation efforts on the watershed and subwatershed scale. The following sections present a description of the SCA protocol employed, an overview of the streams that were assessed, and general results for the Liberty Reservoir watershed.

3.6.1 Assessment Protocol

The SCA method is used to quickly assess the physical conditions and identify common environmental problems in a stream corridor. The assessments were conducted in the fall of 2014 by two person field crews from Parsons Brinckerhoff, NMP Engineering Consultants, Inc., and Coastal Resources, Inc. The teams walked the subset of streams in the Liberty Reservoir watershed that were selected based on accessibility, owner permission, and stream feature (single and double line streams). Following the SCA method, each field crew looked for the following environmental problems during the assessment.

- Channel Alteration Sites (CA)
- Erosion Sites (ES)
- Exposed Pipes (EP)
- Fish Migration Barriers (FB)
- Inadequate Stream Buffers (IB)
- In or Near Stream Construction (IC)
- Pipe Outfalls (PO)
- Trash Dumping (TD)
- Unusual Conditions or Comments (UC)

Field teams walked the selected stream corridors while noting the location of the problem sites on field maps and filling out the appropriate data forms at each site using a GPS handheld unit. Electronic field forms were based on guidance provided in DNR's SCA manual, with slight modifications made by Baltimore County EPS for more efficient data collection and management. At least one photograph was taken at each site to document the conditions observed. Each site was assigned a unique identification number according to the map grid ID number, followed by a sequential site number, and two letters representing the type of problem as shown in the list above. The map grid is based on a 200 scale grid system used by Baltimore County for generating tabloid size field maps and assigning unique IDs to field data items. For segments of erosion sites with similar characteristics observed multiple times along the stream (for example, every outside bend over a 700 foot segment), the same site ID number was used for each section.

SCA problem sites were rated on a scale of one to five indicating the severity of the problem from minor to severe. Severity is a measure of how serious a problem site is compared to other problems within the same category. The most severe problems are those with a direct impact on stream resources. The severity ratings are intended to help prioritize potential restoration opportunities, ranging from a score of 5 which represents a minor problem, to a score of 1 denoting the worst or most severe observed.

3.6.2 Summary of Sites Investigated

SCAs were conducted in the Cliffs Branch, Keyser Run, and Norris Run subwatersheds of the Liberty Reservoir watershed. Streams assessed were determined using county GIS hydrology lines data along single line and double line streams, disregarding other feature types such as intermittent streams and drainage connectors. Landowner permission was required by mail for all private properties located along the proposed stream corridors. Stream corridors that were located on properties whose landowner denied permission for an assessment or whose reaches could not be accessed were not included in the SCAs. In addition, during the field assessment, it was determined that several tributaries of the proposed stream corridors were ephemeral (intermittent) and did not show any signs of erosion; therefore they were not assessed. Conversely, if a stream feature type was listed as intermittent in the GIS but was found to be perennial in the field, it was assessed. Based on these criteria, a total of 23 miles of stream were assessed, herein referred to as surveyed streams. Table 3-20 summarizes the total miles of surveyed streams in each subwatershed.

Table 3-20: Surveyed Streams in Liberty Reservoir Watershed

Subwatershed	Surveyed Stream Miles
Cliffs Branch	11.1
Keyser Run	3.9
Norris Run	7.8
Total	***22.8***

Figure 3-6 shows the location of the SCA area and surveyed streams with respect to the overall Liberty Reservoir watershed. Figure 3-7 shows the stream network within the SCA area, the streams actually surveyed are shown in dark blue. This figure also shows plots of land where landowner permission was denied and illustrates why certain stream segments could not be assessed.

As described previously, SCA problem sites were assigned unique identification numbers according to a map grid ID number. Each site was numbered sequentially during the assessment. The map grid used for the Liberty Reservoir SCAs is shown in Figure 3-7. The field teams walked stream segments by map number. For example, the first SCA problem site located in Cliffs Branch within map number “031A2” was an inadequate buffer site, and was numbered as 01-IB; the remaining sites were numbered consecutively (regardless of type) along the remaining stream segments within the map (i.e. 02-ES, 03-ES, 04-UC, etc.). This same numbering convention was implemented using the map grid within all three subwatersheds assessed.

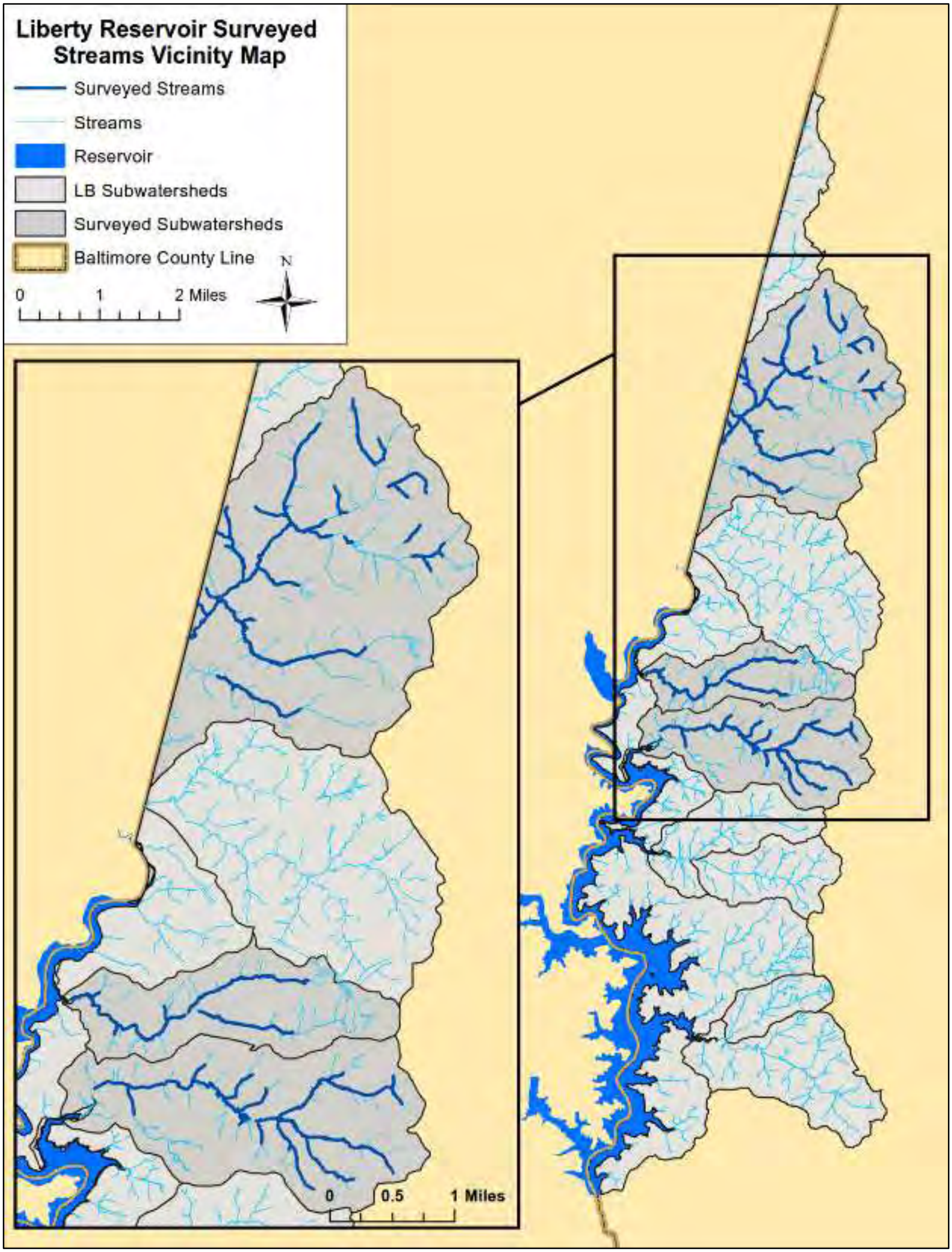

Figure 3-6: Location of Surveyed Streams in Liberty Reservoir Watershed

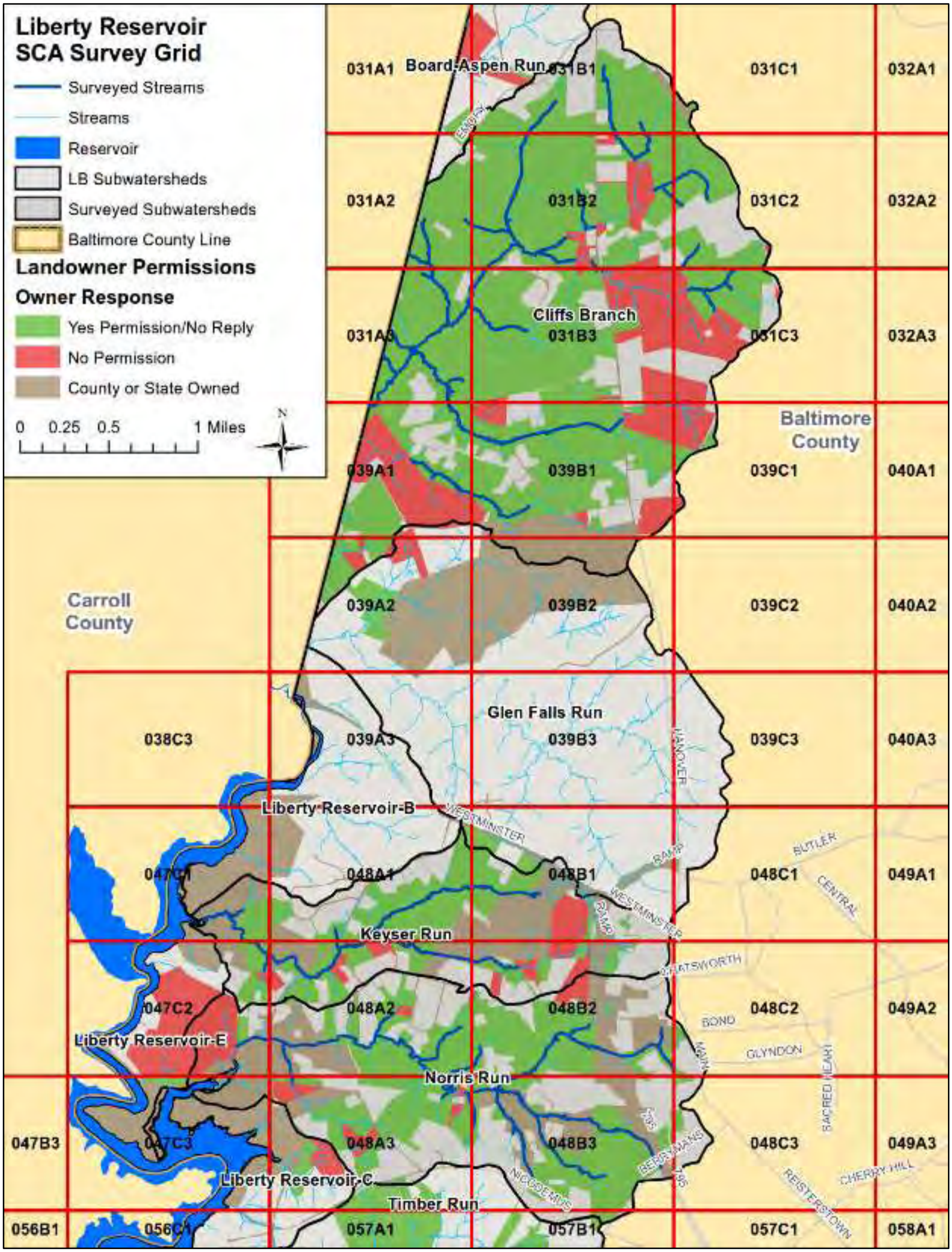

Figure 3-7: Liberty Reservoir SCA Survey Grid and Map Numbers

3.6.3 General Findings

Along the 23 miles of stream assessed within the Liberty Reservoir watershed 597 potential environmental problem sites were observed. The total number of problem sites observed within each subwatershed is summarized in Table 3-21.

Table 3-21: Liberty Reservoir SCA Survey Results - Number of Potential Problems

Subwatershed	Inadequate Buffer	Erosion Sites	Trash Dumping	Fish Barriers	Pipe Outfalls	Exposed Pipes	Channel Alteration	Unusual Conditions or Comments	Total
Cliffs Branch	54	198	9	35	7	1	19	14	337
Keyser Run	16	106	5	17	5	0	8	16	173
Norris Run	21	10	1	26	3	0	11	15	87
Total	***91***	***314***	***15***	***78***	***15***	***1***	***38***	***45***	***597***

Sites assessed as unusual conditions include field observations and may not necessarily reflect an environmental problem. These conditions will be discussed in further detail in subsequent sections. Erosion sites were the most frequent problem observed (314) followed by inadequate buffers (91) and fish barriers (78). Exposed pipes were the least common potential problem. No in or near stream construction was observed during the stream assessments. A summary of the lengths of channel alterations, erosion sites, and inadequate buffers are summarized in Table 3-22 for the Liberty Reservoir watershed. A description of each potential problem category is provided in the proceeding sections.

Table 3-22: Liberty Reservoir Subwatershed Survey Results – Length of Potential Problems

Subwatershed	Length of Channel Alteration (ft.)	Length of Erosion (ft.)	Length of Inadequate Buffer (ft.)
Cliffs Branch	351	17,734	26,463
Keyser Run	154	8,133	9,761
Norris Run	729	693	3,457
Total	***1,234***	***26,561***	***39,680***

Data collected in the field for the SCA are compiled in tables included in Appendix A.

3.6.3.1 Inadequate Stream Buffers

Forested buffer areas along streams are important for improving water quality for flood mitigation as they provide stream bank stabilization through their root systems, reduce the rate of surface runoff, supply shade to streams, remove pollutants such as nutrients and sediments from runoff, and provide habitat for various types of terrestrial and aquatic life, including fish. For the SCA, a stream buffer was considered inadequate if it was less than 50 feet wide from the edge of either stream bank. Inadequate stream buffers were observed in all three subwatersheds assessed. The field teams identified 91 inadequate buffer sites with a total length of approximately 7.5 miles. This equates to approximately 33% of the total streams surveyed having inadequate buffer on one or both stream banks.

The severity of inadequate stream buffers was rated according to length and width. The most severe rating (very severe) of 1 would be given to inadequate buffer lengths with limited or no trees on either stream bank and no evidence that a tree buffer is beginning to form for a significant length of stream. The existing land use was also taken into consideration, such as pavement, lawn, agriculture, or shrubs and trees. The highest inadequate buffer rating assigned in the three assessed subwatersheds was severe. Four of the sites were in Cliffs Branch while Keyser Run and Norris Run each contained one severe rating. Two of the sites are shown in Figure 3-8. Most sites were rated between moderate (3) and minor (5). Stream buffer restoration potential depends on various factors such as accessibility, property ownership, and current land use. Many of the more severe inadequate buffer sites in the watershed were due to land clearing up to the stream banks for use as cropland or pasture leaving the stream completely unshaded.

Figure 3-8: Examples of Severe Inadequate Stream Buffer Locations in Cliffs Branch

Table 3-23 below summarizes the number of inadequate buffer sites associated with each severity rating. The total length of inadequate buffer in each subwatershed and the percentage of surveyed streams having inadequate buffer are also shown.

Table 3-23: Liberty Reservoir SCA Survey Results - Inadequate Stream Buffers

	SEVERITY RATING						LENGTH		
	Very Severe				Minor				% of Surveyed
Subwatershed	1	2	3	4	5	Total	ft.	mi	Streams
Cliffs Branch	0	4	12	18	20	54	26,463	5.0	45.2%
Keyser Run	0	1	5	4	6	16	9,761	1.8	46.8%
Norris Run	0	1	4	4	12	21	3,457	0.7	8.4%
Total	***0***	***6***	***21***	***26***	***38***	***91***	***39,680***	***7.5***	***32.9%***

The majority of the inadequate buffer sites (59%) were located in Cliffs Branch subwatershed; approximately 33% of all streams assessed were identified as having some sort of inadequate buffer. Many of the inadequate buffers are due to cropland and pastures bordering stream segments or lawns as seen in Figure 3-9. Approximately 93% of the inadequate buffer sites ranked between minor to moderate in severity. Of the 94 sites, roughly 29% were reported as being unshaded on both banks; these conditions can be detrimental to aquatic life as shade protects streams from excessive solar heating. The locations of stream segments with inadequate buffers and their corresponding severity ratings are shown in Figure 3-10. Appendix A provides tables of inadequate buffer data ranked by severity for the Liberty Reservoir watershed.

Figure 3-9: Example of Inadequate Buffer in Cliffs Branch Due to Lawn (Left) and Keyser Run Due to Cleared Pasture (Right)

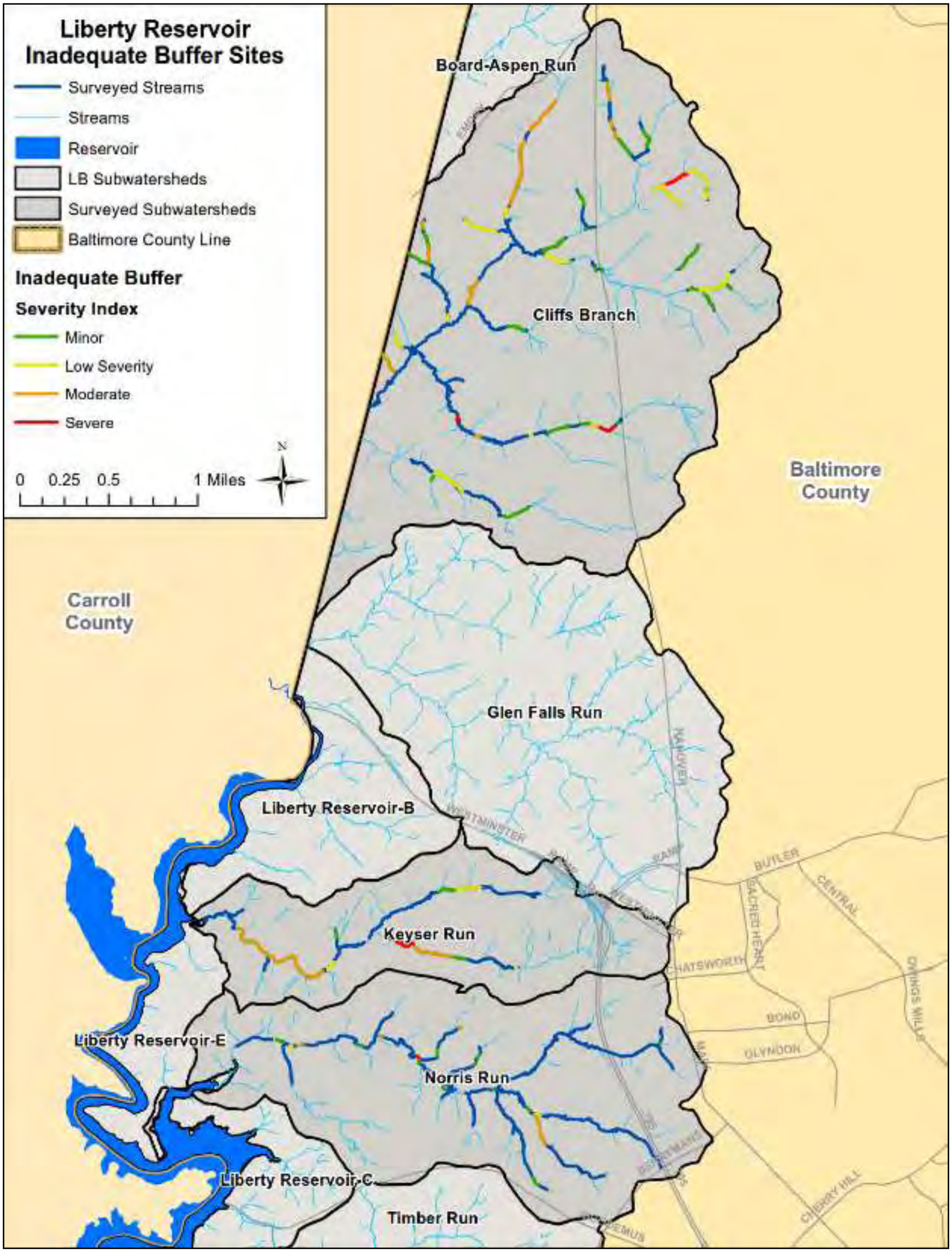

Figure 3-10: Inadequate Stream Buffer Locations in Liberty Reservoir SCA

3.6.3.2 Erosion Sites

Stream bank erosion is a natural process necessary to maintain a healthy aquatic habitat. Conversely, too much erosion can have the opposite effect on a stream system by destabilizing banks, destroying in-stream habitat, and causing sediment pollution problems downstream. Significant erosion problems are the result of changes to stream hydrology or sediment supply which is often attributed to land use changes in a watershed (e.g., urbanization, increased impervious cover, clearing for cropland). This results in a much greater in-stream flow rate during storm events and leads to eroded streambeds and banks. Although streams in forested areas may have adequate 50 foot forest buffers, they can also experience erosion problems due to these high flows from upstream.

Because erosion is a natural process, it was not the purpose of the SCA survey to identify every erosion occurrence. Significant erosion sites were defined by vertical stream banks with exposed soil and overall instability. The type of erosion, possible cause, adjacent land use, and whether there was a threat to nearby infrastructure was noted for each erosion site.

Table 3-24 summarizes the number of erosion sites identified in the Liberty Reservoir subwatershed and their severity rating. Appendix A provides tables of erosion site data ranked by severity for the Liberty Reservoir watershed.

Table 3-24: Liberty Reservoir SCA Survey Results - Erosion Sites

	SEVERITY RATING						LENGTH*		
	Very Severe				Minor				
Subwatershed	1	2	3	4	5	Total	ft.	mi	% of Surveyed Streams
Cliffs Branch	2	6	18	39	132	198	17,734	3.4	30.3%
Keyser Run	0	2	8	49	47	106	8,133	1.5	39.0%
Norris Run	0	0	0	2	7	10	693	0.1	1.7%
Total	***2***	***8***	***26***	***90***	***188***	***314***	***26,561***	***5.0***	***22.0%***

*left and right banks are counted individually and stream length may overlap in some cases

A total of 314 erosion sites were documented. Erosion was the most documented problem identified from the SCA surveys. The length of stream channel identified with erosion totaled 5 miles (although left and right bank were summed individually and in some cases may overlap). During the Liberty Reservoir stream assessments, the channel condition of erosion sites were classified as one of four stages, based on a condensed version of the Channel Evolution Model (CEM): Stage I- Incision, Stage II- Widening, Stage III- Deposition; and Stage IV- Recovery and Reconstruction. This classification helps identify the direction of current trends in a stream channel and match restoration solutions to its current behavior. The channel condition for nearly all of the erosion sites were either Stage I Incision (54.9%) or Stage II Widening (45.0%). Stage I Incision describes a channel that is downcutting, which liberates sediment and creates unstable banks. Stage II Widening often results in widespread bank failures as high flows undercut banks because they can no longer access the floodplain; the most significant erosion hazard occurs during this phase. Stage II- Widening is usually found at a meander bend and/or associated with steep slopes. Some of this type of erosion could be described as a natural process. Both of the "very severe" erosion sites were classified as Stage I-Incision and were in first order or headwater tributaries. Streams in the incision stage have the most potential for prolonged degradation and may contribute large amounts of sediment downstream through the channel evolution process.

Figure 3-11 shows an example of a very severe and severe erosion site. The figure on the left is of site 031C2_09-ES a very severe erosion site near Old Hanover Road with eight foot vertical bank heights over a 250 foot distance. The figure on the right is of site 039A1_02-ES, a severe erosion site in Cliffs Branch with nine foot vertical bank heights over a 70 foot distance. The very severe erosion site is incising, while the severe erosion site is widening at a bend. The location of all erosion sites can be seen in Figure 3-12.

Figure 3-11: Example of a Very Severe Erosion Site (Left) and a Severe Erosion Site (Right) both located in Cliffs Branch

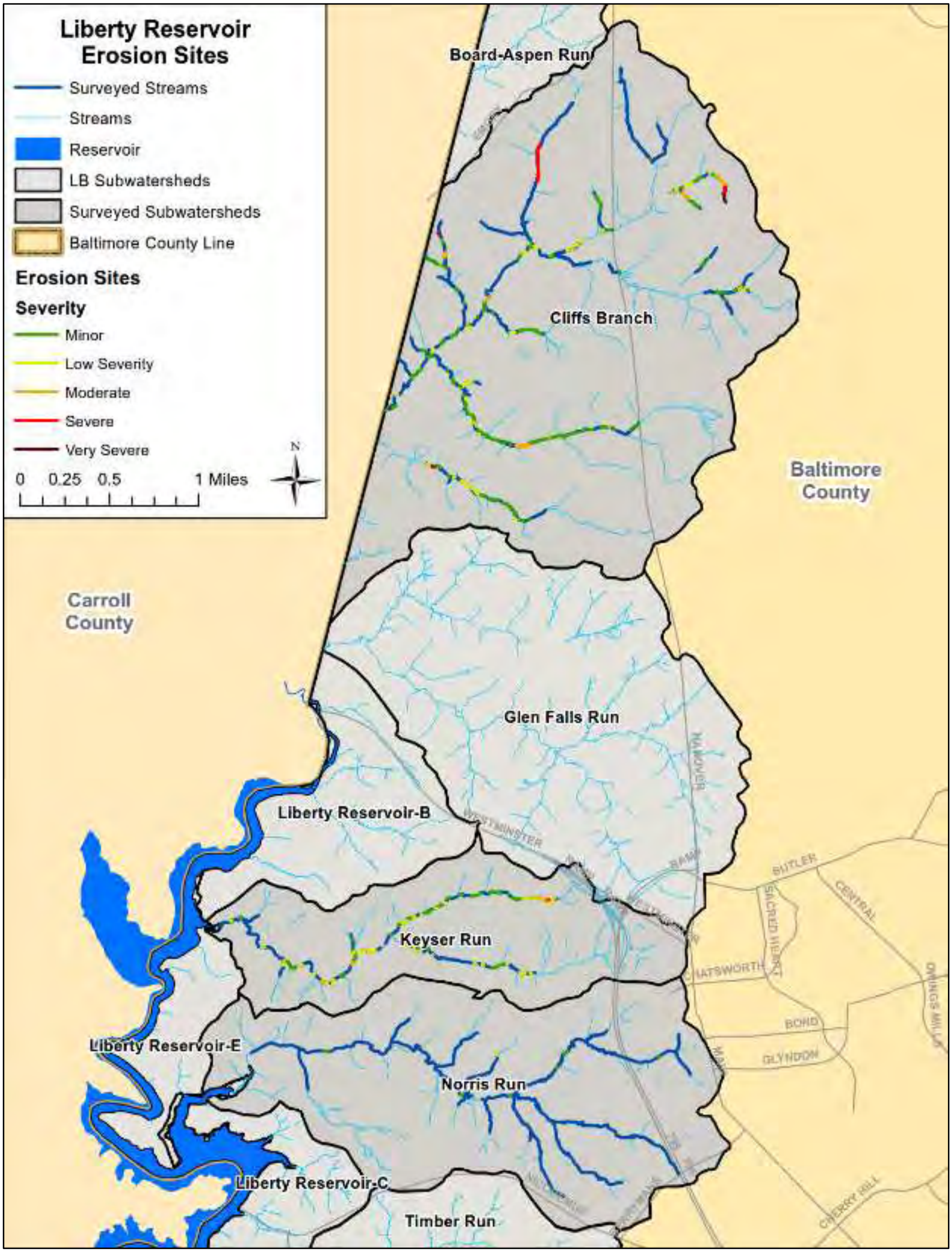

Figure 3-12: Location of Erosion Sites in the Liberty Reservoir Watershed

3.6.3.3 Fish Migration Barriers

Fish migration barriers refer to anything in the stream that significantly interferes with the upstream movement of fish. Unobstructed upstream movement is important for various species of fish that move up and downstream during different cycles of their life such as spawning. Fish barriers can reduce the fish population and diversity in stream sections. These barriers include manmade structures such as dams or roadway culverts and natural features such as waterfalls or debris jams. Three main problems regarding fish barriers were evaluated when identifying blockages: 1) vertical drop is too high (>6 inches) for fish to swim over; 2) water depth is too shallow such as when water is spread over a large area at channelized sections or road crossings; and 3) water is moving too fast such as when a steep culvert pipe is discharging high velocity flow. The variety of barrier is also noted, including man-made dam, debris dam, road or pipe crossing, natural falls, beaver dam, pond, or other causes.

The severity of the barrier was rated based on location in the stream network and whether the blockage was total, partial, or temporary. A fish migration barrier was considered very severe when a structure completely blocked a large stream. A minor rating was assigned to temporary and/or natural fish barriers that blocks little in-stream habitat. Locations of fish migration barrier sites are shown on Figure 3-22 through Figure 3-24. Table 3-25 summarizes the number of fish migration barrier sites identified in the Liberty Reservoir watershed and their severity rating. Appendix A provides tables of fish migration barrier site data ranked by severity for the Liberty Reservoir watershed.

Table 3-25: Liberty Reservoir SCA Survey Results - Fish Passage Barriers

	SEVERITY RATING					
	Very Severe				Minor	
Subwatershed	**1**	**2**	**3**	**4**	**5**	**Total**
Cliffs Branch	0	1	6	8	20	35
Keyser Run	1	2	6	3	5	17
Norris Run	0	1	4	9	12	26
Total	***1***	***4***	***16***	***20***	***37***	***78***

Figure 3-13 shows a very severe and severe road crossing fish barrier where the drop between the culvert and the natural channel is too high for the fish to pass and/or too shallow. Figure 3-14 shows two naturally occurring fish migration barrier sites due to natural falls that are too high and too fast for fish to pass through. In all cases, the location of the fish barrier within the subwatershed has an impact on the severity rating.

Figure 3-13: Example of a Very Severe Road Crossing Fish Barrier in Keyser Run (Left) and Moderate Road Crossing Fish Barrier in Norris Run (Right)

Figure 3-14: Examples of Low Severity (Left) and Moderate (Right) Natural Falls Fish Barriers in Keyser Run

3.6.3.4 Pipe Outfalls and Exposed Pipes

Pipe outfalls include pipes or small manmade channels that discharge into the stream. They are considered a potential environmental problem because they can carry uncontrolled runoff and pollutants such as oil, heavy metals, and nutrients into a stream system. Pipe outfalls can also create significant erosion problems as high flows without proper velocity dissipation can lead to extensive erosion and scour in the receiving channel; separate erosion sites were also documented if necessary at pipe outfall locations. The severity rating for a pipe outfall was primarily based on the discharge including whether discharge was present, color, odor, amount, and downstream impacts (not including erosion, which was assessed separately).

A total of 15 pipe outfalls were surveyed during the SCAs in Liberty Reservoir (Table 3-26). The highest severity rating for pipe outfalls was moderate, shown in Figure 3-15.

Table 3-26: Liberty Reservoir SCA Survey Results - Pipe Outfalls

	Very Severe				Minor	
Subwatershed	1	2	3	4	5	Total
Cliffs Branch	0	0	1	3	3	7
Keyser Run	0	0	1	0	4	5
Norris Run	0	0	0	2	1	3
Total	***0***	***0***	***2***	***5***	***8***	***15***


Figure 3-15: Moderate Pipe Outfalls with Active Discharge

Exposed pipes were also assessed and include any pipes that are in the stream or along the stream's immediate banks that could be damaged by a high flow event. Exposed pipes include manhole stacks, pipes exposed along the stream banks or under the stream bed, and pipes built over a stream but that are low enough to be affected by frequent high storm flows. These pipes can be vulnerable to puncture by debris in the stream and pose a threat to water quality depending on the contents within the pipe.

Only one exposed pipe was observed during the Liberty Reservoir SCAs (Table 3-27). The exposed pipe in Cliffs Branch had an unknown use, was found running perpendicular with the stream, and was completely exposed across the entire bottom width of the channel with a high risk of puncture (Figure 3-16).

Table 3-27: Liberty Reservoir SCA Survey Results - Exposed Pipes

	Very Severe				Minor	
Subwatershed	**1**	**2**	**3**	**4**	**5**	**Total**
Cliffs Branch	0	0	1	0	0	1
Keyser Run	0	0	0	0	0	0
Norris Run	0	0	0	0	0	0
Total	***0***	***0***	***1***	***0***	***0***	***1***

Figure 3-16: An Exposed Pipe in Cliffs Branch with Moderate Severity

3.6.3.5 Channel Alterations

Channel alterations refer to significantly altered channel or stream banks from their naturally occurring structure or condition. This includes channelized stream sections where a stream channel has been straightened, widened, deepened, or lined with concrete or rock. This can increase flow rates and decrease habitat and nutrient uptake in the waterway.

Channelized streams are typically intended to convey more water and to prevent flooding but often create adverse environmental impacts such as impairing habitat and increasing water temperature. Table 3-28 summarizes the number and length of channel alteration sites in each subwatershed and their associated severity rating. Locations of channel alteration sites are shown on Figure 3-22 through Figure 3-24. Appendix A provides tables of channel alterations site data ranked by severity for the Liberty Reservoir watershed.

Table 3-28: Liberty Reservoir SCA Survey Results - Channel Alterations

	SEVERITY RATING						LENGTH		% of Surveyed Streams
	Severe				Minor				
Subwatershed	1	2	3	4	5	Total	ft.	mi	
Cliffs Branch	0	0	4	7	8	19	351	0.07	0.6%
Keyser Run	0	0	2	1	5	8	154	0.03	0.7%
Norris Run	0	0	5	2	4	11	729	0.14	1.8%
Total	***0***	***0***	***11***	***10***	***17***	***38***	***1,234***	***0.2***	***1.0%***

A total of 38 channel alteration sites were documented during the survey for a total length of 1,234 feet or 1.0% of the entire stream lengths surveyed. Moderate channel alterations were the highest ranking for the Liberty Reservoir watershed. The remaining sites inventoried for channel alterations, ranked either low severity or minor. Multiple channel alterations consist of a segment of stream that has been converted to a private roadway, either by creating a ford for the road to pass through the stream or putting the stream through a culvert for the road to pass above the stream (Figure 3-17, left). Another common type of channel alteration observed throughout the Liberty Reservoir watershed was boulder structures and riprap placed along banks for stabilization (Figure 3-17). The channel alteration sections identified in the Liberty Reservoir watershed consist of relatively short stream lengths and would not represent major opportunity for water quality improvements. Many channel alterations are expensive and challenging to correct. Channel alterations were not identified as a significant issue impacting water quality or stream health in the Liberty Reservoir watershed based on the results of the SCA surveys.

Figure 3-17: Examples of two moderate Channel Alteration for the creation of private roads either by piping the stream as shown in Cliffs Branch (Left) or by creating a ford to pass through the stream as shown in Keyser Run (Right)

Figure 3-18: Example of Channel Alteration due to Rip-Rap in Cliffs Branch (Left) and a Sand Bag Dike in Norris Run (Right)

3.6.3.6 *Trash Dumping*

Trash dumping sites are locations where large amounts of trash are inside the stream corridor; either as a site of deliberate dumping or as a place where trash tends to accumulate (often as a result of wind or storm drainage). Identifying trash dumping sites serves two main purposes: 1) to limit access to the areas of the stream corridor where dumping and accumulation is a problem and 2) to encourage volunteer stream clean-ups which promote community involvement and raises awareness among the community of the condition of their local streams. Site severity was based on amount of trash (estimated in terms of pick-up truck loads), type of trash, and potential impact on the stream. The type of trash was classified under the following: residential, industrial, yard waste, floatables, tires, construction, or other. Table 3-29 summarizes the number of trash dumping sites in each subwatershed and their associated severity rating. A total of 15 trash dumping sites were observed throughout the three subwatersheds assessed. Figure 3-19 shows the examples of trash dumping sites. The site on the left was given a severe ranking with a mixture of tires, construction, and household waste while the site on the right received a moderate ranking and consisted of construction materials along the stream banks.

Table 3-29: Liberty Reservoir SCA Survey Results - Trash Dumping

Subwatershed	Very Severe 1	2	3	4	Minor 5	Total
Cliffs Branch	0	1	2	3	3	9
Keyser Run	0	0	0	2	3	5
Norris Run	0	0	0	1	0	1
Total	***0***	***1***	***2***	***6***	***6***	***15***

Figure 3-19: Examples of Severe (Left) and Moderate (Right) Trash Dumping Sites in Cliffs Branch

3.6.3.7 *Unusual Condition or Comments*

Unusual conditions and comments were used to document the location of anything out of the ordinary or to identify and describe a specific problem observed in the field. An unusual condition was ranked as very severe if the potential problem was considered to have a possible direct and wide-reaching impact on the stream's aquatic resources and rated as minor if it was considered to have no significant impact on aquatic resources.

Table 3-30 summarizes the number of unusual conditions sites and their severity rating. Only three severe unusual conditions were observed; the remaining 33 unusual conditions were rated moderate or below. Examples of some of the unusual conditions observed are shown in Figure 3-20. One common unusual condition was the presence of all-terrain vehicle (ATV) trails that crossed the streams. Locations of unusual conditions sites are shown on Figure 3-22 through Figure 3-24. Appendix A provides tables of unusual conditions site data ranked by severity for the Liberty Reservoir watershed.

Table 3-30: Liberty Reservoir SCA Survey Results - Unusual Conditions

SEVERITY RATING

Subwatershed	Very Severe 1	2	3	4	Minor 5	Total
Cliffs Branch	0	0	1	2	10	13
Keyser Run	0	1	1	5	6	13
Norris Run	0	2	2	1	5	10
Total	***0***	***3***	***4***	***8***	***21***	***36***

Figure 3-20: Examples of Unusual Conditions – Remnant dam structure with a stream bypass in Norris Run (Left) and ATV trail stream crossing in Keyser Run (Right)

Table 3-31 summarizes the number of sites with comments and their severity rating. One comment site was rated moderate and was the highest rating given; the remaining eight sites were low severity and minor rankings. A couple of examples of unusual comments are shown in Figure 3-21. Locations of sites with comments are shown on Figure 3-22 through Figure 3-24. Appendix A provides tables of comment site data ranked by severity for the Liberty Reservoir watershed.

Table 3-31: Liberty Reservoir SCA Survey Results – Comments

	SEVERITY RATING					
Subwatershed	Very Severe 1	2	3	4	Minor 5	Total
Cliffs Branch	0	0	0	0	1	1
Keyser Run	0	0	0	1	2	3
Norris Run	0	0	1	2	2	5
Total	***0***	***0***	***1***	***3***	***5***	***9***

Figure 3-21: Examples of Comments – Debris Jam Upstream of Box Culvert (Left) and a mint patch growing in the middle of the channel (Right)

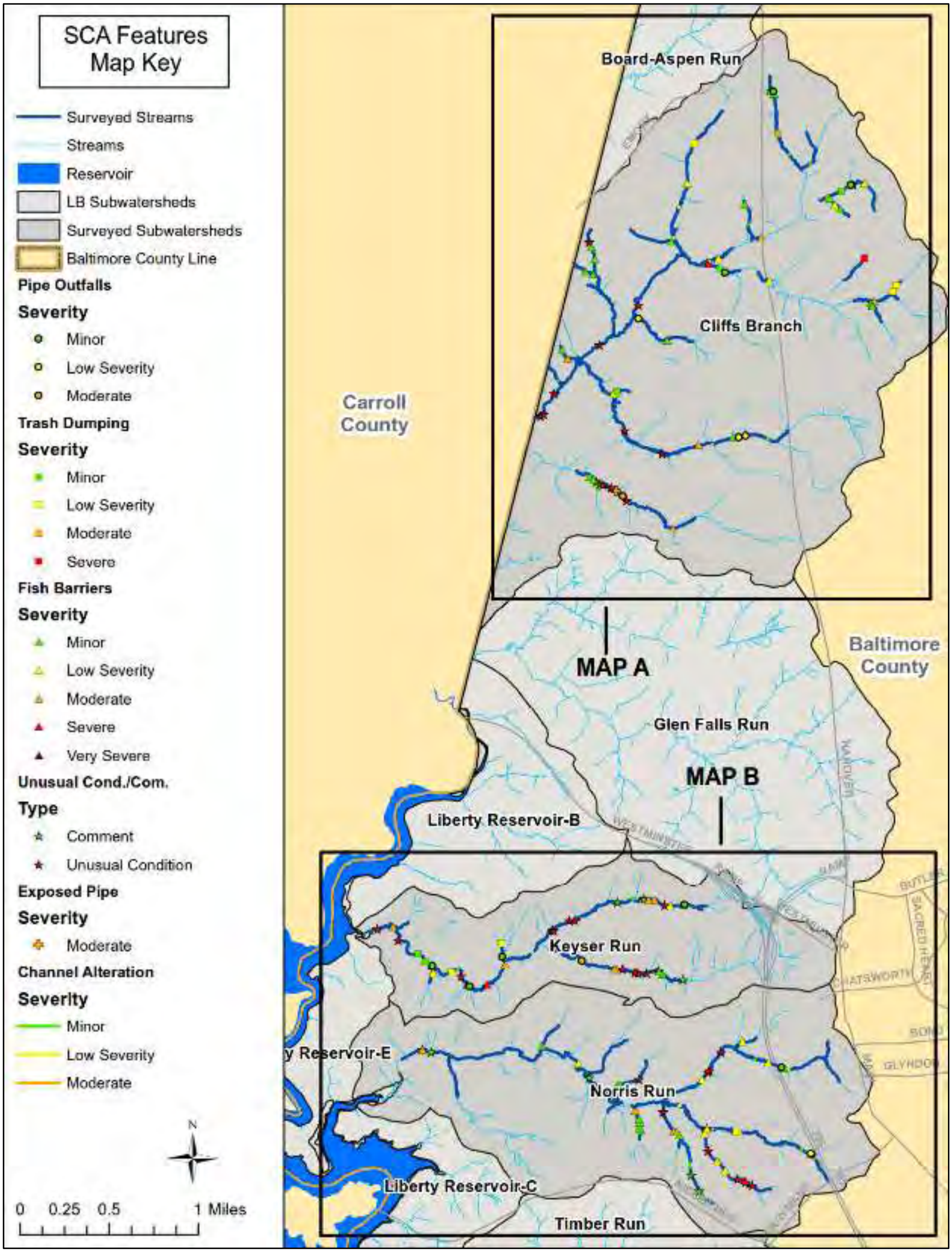

Figure 3-22: Location of Other SCA Problem Sites in the Liberty Reservoir Watershed: Key Map

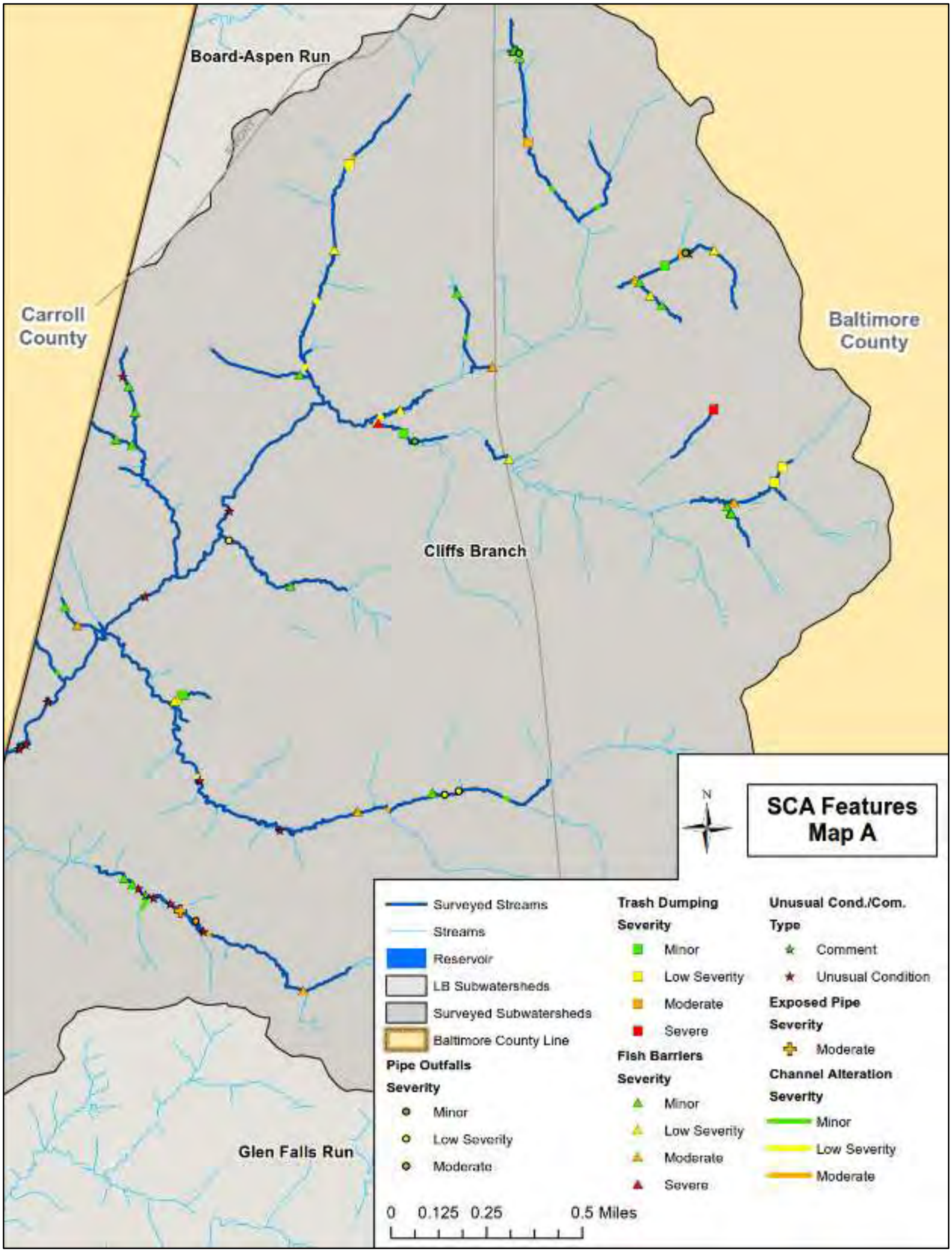

Figure 3-23: Location of Other SCA Problem Sites in Liberty Reservoir: Map A

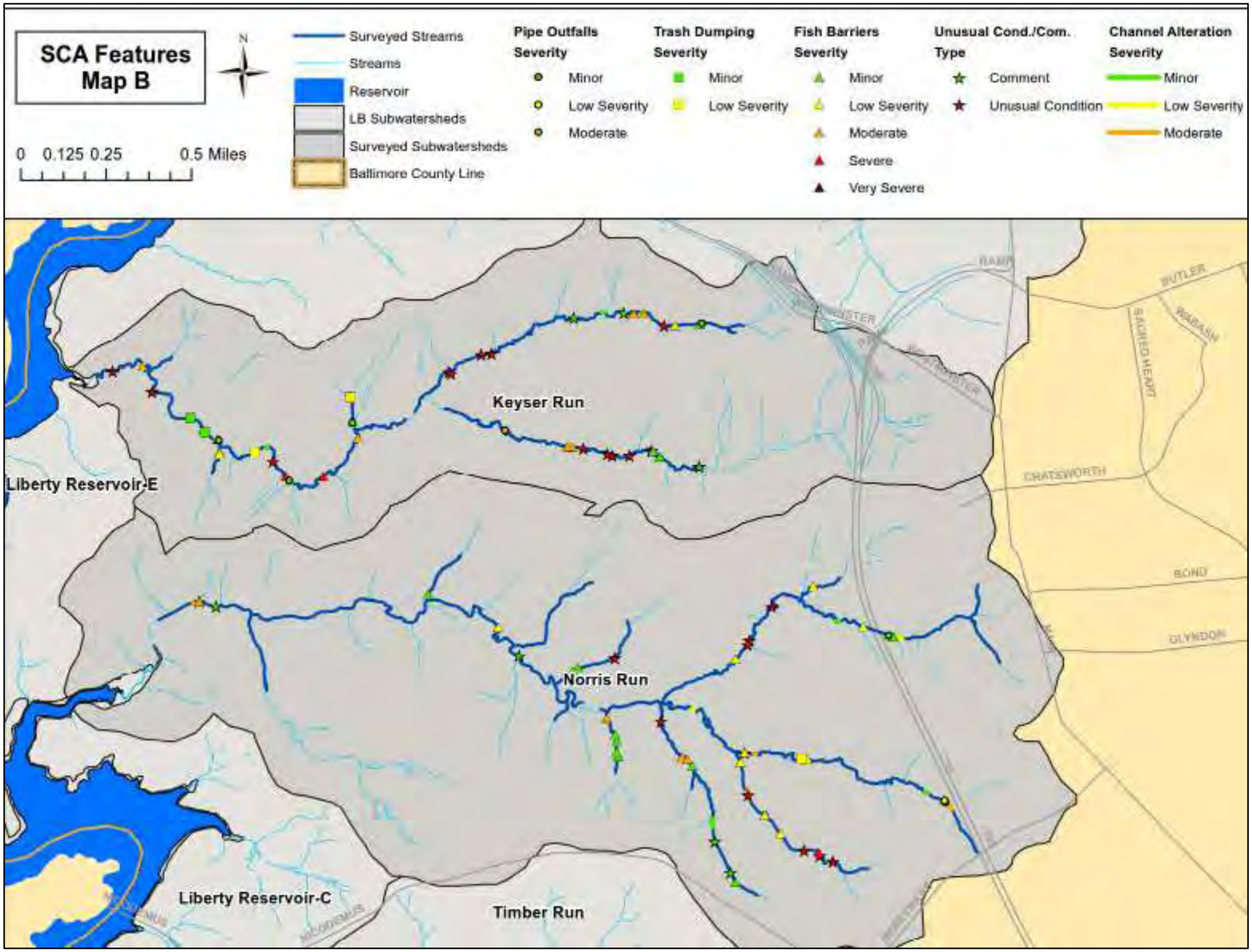

Figure 3-24: Location of Other SCA Problem Sites in Liberty Reservoir: Map B

3.7 Sewer Overflow Impacts

At present, Sanitary Sewer Overflows (SSOs) and combined sewer overflows (CSOs) are inevitable byproducts of the expanding population and aging sewer systems. Sewer overflows can be caused by various factors such as severe weather, insufficient maintenance, pumping station equipment malfunction, electrical outage, sewer line breaks, improper disposal of fats and grease, and vandalism. Raw sewage can enter nearby streams when flows exceed the sanitary sewer system's capacity or if the infrastructure fails. USEPA reports that there are at least 23,000 - 75,000 incidents per year (not including sewage backups into buildings). Environmental and human health consequences of these overflows can be serious. *E. coli* bacteria and other pathogens are typically present in raw sewage and can pose health risks to individuals who may come into contact with contaminated water. Sewer overflows can also contain high levels of nutrients (nitrogen and phosphorus) which are toxic to aquatic life and can lead to depletion of oxygen in waterways. High levels of sediment are also present in sewer overflows, which can clog streams and block sunlight from reaching essential aquatic plants.

In September 2005, USEPA and MDE issued a consent decree to Baltimore County with deadlines to reduce and eliminate sanitary sewer overflows. Implementation of work in compliance with the consent decree, such as capital projects, equipment upgrades, and operations improvements, will reduce nutrients and bacteria entering streams in the Liberty Reservoir watershed. However, this may not address all impacts associated with the sanitary sewer system since the consent decree only targets overflows. For example, leaks that are not associated with an overflow may occur in the sanitary sewer system. Depending on the location of the leaks, which are typically at joints, there may still be adverse impacts to the stream system from the sanitary sewer system.

The number of SSO events documented in the Liberty Reservoir watershed and approximate volume discharged between 2000 and 2013 are summarized in Table 3-32 and based on Baltimore County's SSO spatial data. Table 3-32 also summarizes the estimated pollutant loads associated during this 14-year period.

Table 3-32: Sanitary Sewer Overflow Volumes and Pollutant Loads in Liberty Reservoir (2000-2013)

Subwatershed	Year	# of SSO Events	Volume of Overflow (gal)	TN (lbs.)	TP (lbs.)	FC (MPN)
Keyser Run	2004	1	700	0.174	0.058	1.68E+11
Keyser Run	2004	1	50	0.012	0.004	1.2E+10
Total		***2***	***750***	***0.187***	***0.062***	***1.8E+11***

Pollutant load estimates were calculated based on the following assumptions:

- **Total Phosphorus (TP):** A conversion factor of 8.3×10^{-5} was used to convert gallons of overflow to pounds of pollutant. This is based on a 10 mg/L TP concentration for raw sewage and a multiplier of 8.3×10^{-6} lb·L/mg·gal.

- **Total Nitrogen (TN):** A conversion factor of 2.5×10^{-4} was used to convert gallons of overflow to pounds of pollutant. This is based on a 30 mg/L TN concentration for raw sewage and a multiplier of 8.3×10^{-6} lb·L/mg·gal.
- **Fecal Coliform (FC):** A conversion factor of 2.4×10^{8} was used to convert gallons of overflow to MPN fecal coliform. This is based on a multiplier of 6.4×10^{6} MPN/100 mL.

Figure 3-25 shows the location of SSO events reported during 2000 to 2013 in the Liberty Reservoir watershed. Both incidents have been documented in the Keyser Run subwatershed. The largest overflow volume was 700 gallons. Both of these areas have the potential for follow-up inspection and addressing SSO problems.

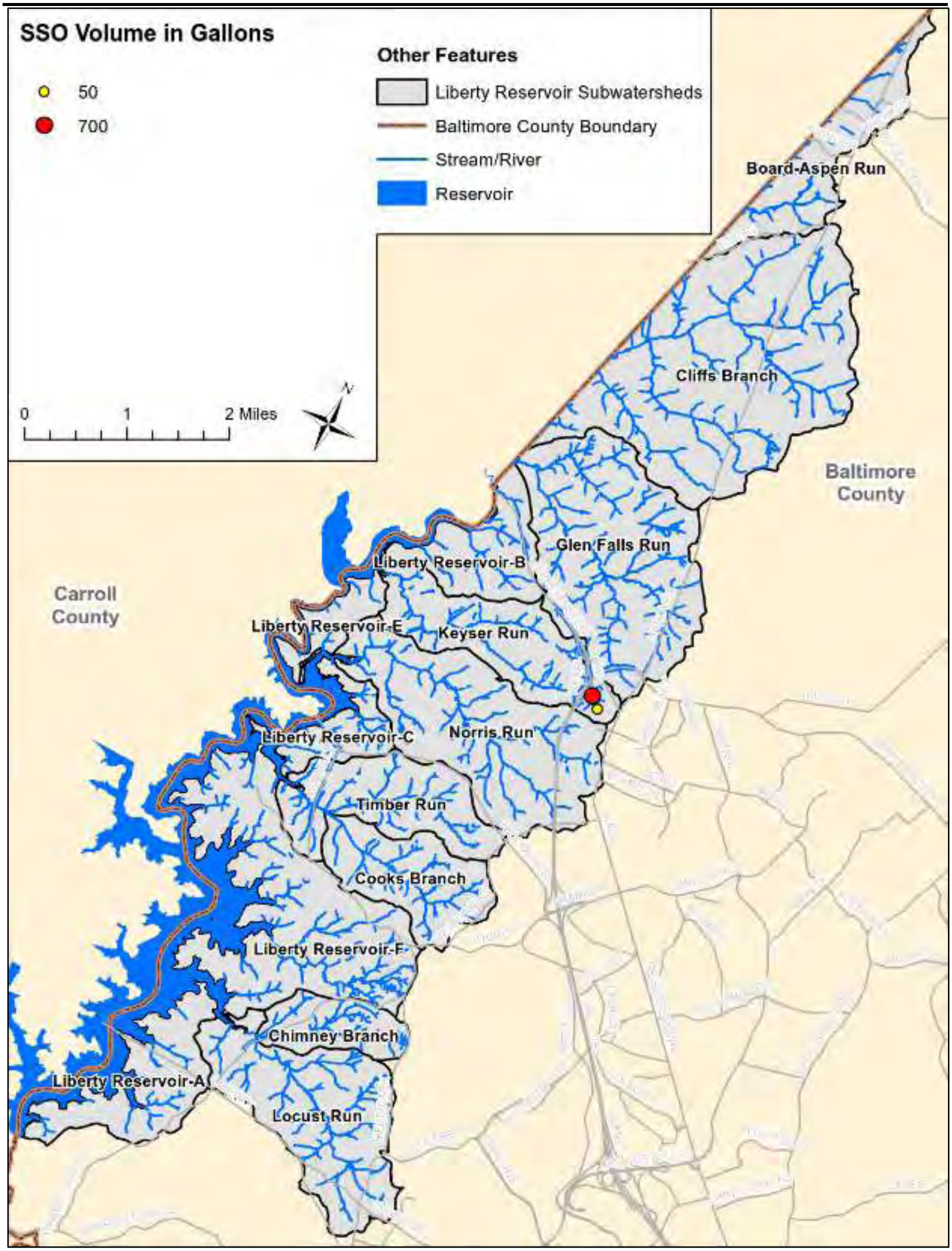

Figure 3-25: Sanitary Sewer Overflow Locations in Liberty Reservoir

CHAPTER 4: UPLANDS ASSESSMENT

4.1 Introduction

Upland areas were assessed according to the Unified Subwatershed and Site Reconnaissance (USSR) Manual developed by the Center for Watershed Protection (CWP) to identify potential pollution sources influencing water quality and to evaluate restoration project opportunities (CWP, 2005). The USSR manual is the last manual in a series of 11 regarding techniques for restoring urban watersheds. It provides detailed guidance for field survey techniques and was developed to help watershed groups, municipal staff, and consultants to quickly identify major stormwater pollution sources and assess subwatershed restoration potential for source controls, pervious area management, and improved municipal maintenance such as education, retrofits, street sweeping, inlet cleaning, and open space management. Upland areas within the Liberty Reservoir watershed were assessed by Parsons Brinckerhoff and NMP Engineering, Inc.

The field survey of upland areas in the Liberty Reservoir watershed included four major components:

- Neighborhood Source Assessment (NSA)
- Hotspot Site Investigation (HSI)
- Institutional Site Investigation (ISI)
- Pervious Area Assessment (PAA)

Each of the above components is described in detail in the following sections.

4.2 Neighborhood Source Assessment (NSA)

NSAs describe pollution source areas, stewardship behaviors, and restoration opportunities within individual neighborhoods. Each neighborhood has unique characteristics which determine the ability to implement restoration projects, source controls, and stewardship practices. The sections below describe the methods used to delineate and assess individual neighborhoods in the Liberty Reservoir watershed.

4.2.1 Assessment Protocol

Prior to conducting NSAs in the field, neighborhoods were delineated using Geographic Information Systems (GIS) data such as tax parcels, historical development information, and aerial photography provided by Baltimore County Office of Information Technology (OIT). A neighborhood was delineated based on a group of homes with similar characteristics including lot sizes, setbacks, year houses were built, and house types (apartment complex, row homes, single family detached, etc.) Neighborhoods defined in the office using available information were verified in the field. Adjustments were made as necessary in the field to group similar neighborhoods or separate dissimilar neighborhoods.

Unique ID numbers were assigned to NSAs using the classification scheme “NSA_S_1000”, where ‘S’ denotes the Liberty Reservoir watershed and the first two digits correspond to a specific subwatershed.

Subwatersheds were assigned unique numbers summarized in Table 4-1 for the purposes of NSAs, HSIs, and ISIs.

Table 4-1: Subwatershed ID Numbers

ID	Subwatershed
01	Board-Aspen Run
02	Cliffs Branch
03	Glen Falls Run
04	Liberty Reservoir-B
05	Keyser Run
06	Liberty Reservoir-E
07	Norris Run
08	Liberty Reservoir-C
09	Timber Run
10	Cooks Branch
11	Liberty Reservoir-F
12	Chimney Branch
13	Liberty Reservoir-A
14	Locust Run

The field team drove through every street in a defined neighborhood to identify potential pollution sources and restoration opportunities. To standardize the NSA process and be able to prioritize potential restoration efforts, data was collected in each neighborhood for four main source areas: yards and lawns; driveways, sidewalks, and curbs; rooftop runoff; and common areas. These are each described briefly below.

Yards and Lawns

Yards and lawns typically represent a significant portion of the pervious cover in a neighborhood and therefore can be a major source of nutrients, pesticides, sediment, and runoff. Maintenance behaviors tend to be similar within individual neighborhoods and certain activities can impact subwatershed quality such as fertilization, pesticide use, water use, landscaping, and waste management. Potential pollution sources evaluated under the yards and lawns category include grass cover and management status (fertilization and irrigation methods), bare soil, swimming pools, and junk or trash. The field team also identified the proportions of impervious cover, grass cover, landscaping, and bare soil within each neighborhood. The amount of existing tree cover and landscaping was then compared to the other cover types to evaluate potential for increasing these features and providing water quality benefits through interception and filtration of stormwater runoff.

Driveways, Sidewalks, and Curbs

Driveways, sidewalks, and curbs are common in neighborhoods and convey runoff to a storm drain system or directly into stream channels. Activities such as car washing, de-icing, and improper chemical storage can contribute pollutants such as nutrients, oil, sediment, and chlorides, into the storm drain system and stream channels. While assessing neighborhoods, data was collected for potential pollution sources including: pet waste (source of bacteria); long-term car parking (unused old cars with potential to leak chemicals, oil, and/or grease); and amount of sediment, organic matter, and/or trash present along curbs. Potential for street tree planting and street sweeping was also evaluated based on some of these factors.

Rooftops

Rooftop runoff is another contributor to stormwater runoff and pollutants in neighborhoods. Downspout retrofits can help reduce runoff and pollutants introduced to local streams. The field team identified whether downspouts discharged rooftop runoff to pervious areas, rain barrels, impervious surfaces (driveways, street), and/or directly to the storm drain system and the proportion of each within a neighborhood. The potential for disconnecting and redirecting downspouts from impervious surface or the storm drain system was also evaluated.

Common Areas

Common areas such as community parks (homeowners open space and/or local open space) and parking lots are good opportunities to observe community behaviors such as pet waste disposal, stormwater management, storm drain marking, and how natural areas or buffers are managed. Good maintenance of these areas indicates that residents or a homeowner's association are active in caring for the neighborhood and may represent opportunities for restoration projects. Data was collected on the condition of storm drain inlets (whether they were clean or filled with debris) and presence of pet waste or dumping in common areas to identify potential pollution sources in a neighborhood. The potential for storm drain marking, stormwater management practices, and stream buffer planting was also evaluated.

Other NSA Information

In addition to these four source areas, basic information was collected in individual neighborhoods to help rate restoration potential. This information included lot size, house types, and whether a homeowners' association exists for the community. Presence of sewer service was also identified for additional potential pollution sources. After surveying the entire neighborhood and completing the basic information and four major source area sections, any major pollutants that are potentially being generated by the neighborhood are indicated on the field form in the following categories: nutrients; oil and grease; trash/litter; bacteria; and sediment. For example, if a neighborhood had several long-term parked vehicles, oil and grease would be flagged as a potential major pollutant being generated in that neighborhood. The presence of trash in yards, dumping in common areas, or overflowing/uncovered dumpsters would be a significant indicator for trash/litter generated in a neighborhood. Sediment was flagged as a major pollutant source if erosion or bare soil was observed, and/or a considerable portion of the curb and gutters were covered with sediment.

Recommended Actions

After evaluation of an entire neighborhood, specific actions were recommended for neighborhood restoration or retrofits based on initial field observations. Recommended actions included in the Liberty Reservoir watershed NSAs included:

- Downspout disconnection
- Fertilizer reduction
- Bayscaping
- Storm drain marking
- Street tree and shade tree planting
- Lot canopy improvement
- Street sweeping
- Trash management

The last step of the NSA involved rating the overall neighborhood pollution severity and restoration potential. The severity of pollution generated by a neighborhood is denoted by the Pollution Severity Index (PSI) based on benchmarks and scoring system in the USSR manual. An NSA PSI is rated as severe, high, moderate, or none. A neighborhood's potential for residential restoration projects is rated as high, moderate, or low according to the Restoration Opportunity Index (ROI). The USSR also provides benchmarks and guidelines to establish NSA ROI ratings.

4.2.2 Summary of Sites Investigated

A total of 32 neighborhoods were assessed throughout the Liberty Reservoir watershed (see Figure 4-1). The number of neighborhoods within each subwatershed is summarized in Table 4-2. Some neighborhoods may overlap multiple subwatersheds; in this case, the neighborhood is counted once for each subwatershed in which it falls. Analyses of acres of land or miles of road addressed by recommended actions, however, are based on the actual proportion of the neighborhood that falls within each watershed. This is explained further in subsequent sections.

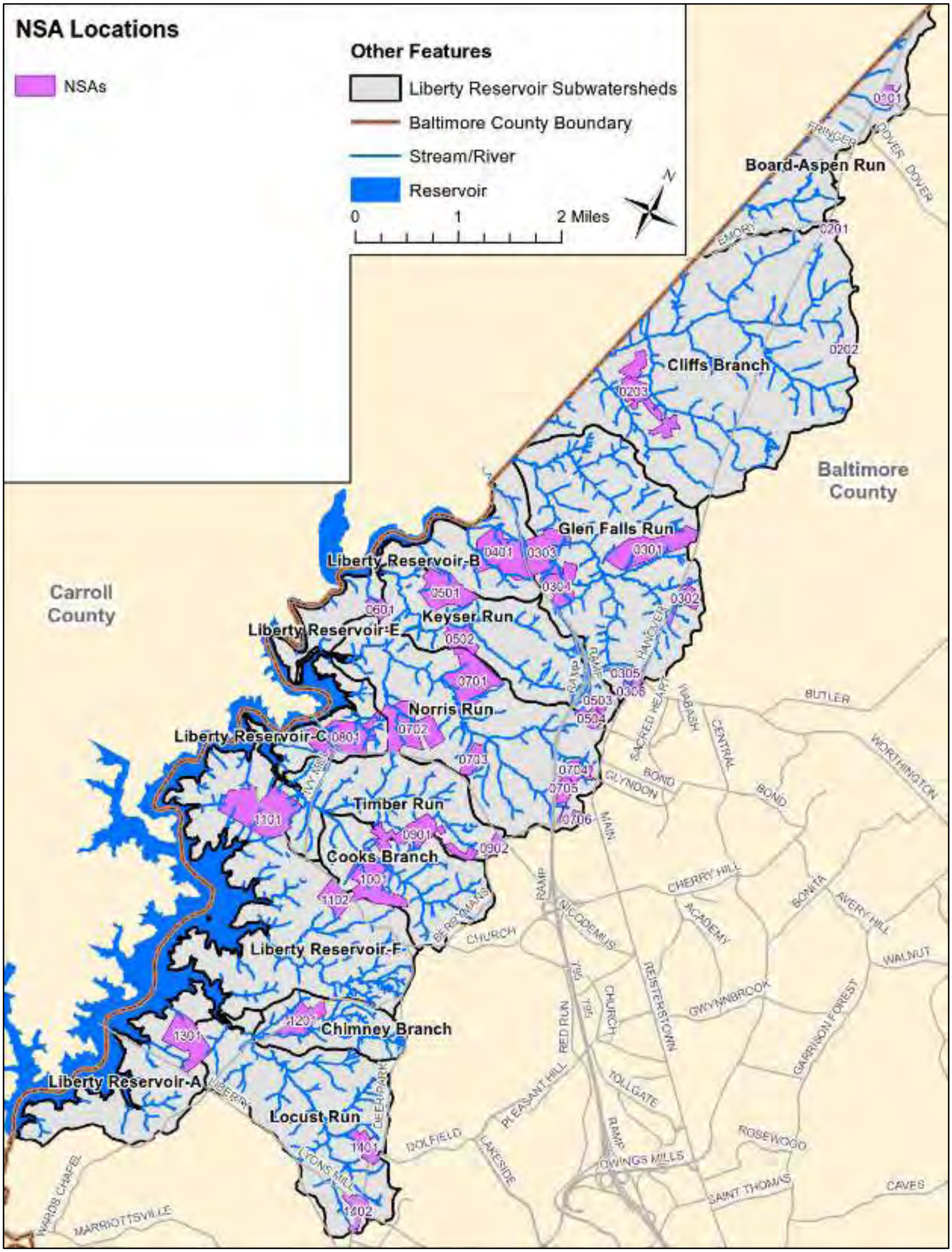

Figure 4-1: Locations of NSAs in the Liberty Reservoir Watershed

Table 4-2: Neighborhoods Surveyed per Subwatershed

Subwatershed	# of NSAs
Board-Aspen Run	1
Cliffs Branch	3
Glen Falls Run	6
Liberty Reservoir-B	3
Keyser Run	6
Liberty Reservoir-E	1
Norris Run	10
Liberty Reservoir-C	2
Timber Run	5
Cooks Branch	3
Liberty Reservoir-F	3
Chimney Branch	1
Liberty Reservoir-A	1
Locust Run	3

Of the neighborhoods assessed, none were rated as having both a high PSI, meaning evidence of a high degree of pollution in the neighborhood, and a high ROI, meaning a high capacity for restoration projects within the neighborhood. Overall, three neighborhoods were rated as having high PSI and 15 neighborhoods were considered to have moderate PSI. Nine neighborhoods were considered as having high ROI; and 15 neighborhoods were rated as having moderate ROI. The remaining neighborhoods had either a low PSI or ROI rating. Of the neighborhoods with high PSI or ROI ratings, two were rated as having high PSI and moderate ROI while six neighborhoods were considered as having moderate PSI and high ROI. These eight neighborhoods represent the best areas to target for restoration initially. The distribution of PSI and ROI ratings among the Liberty Reservoir NSAs are shown in Figure 4-2.

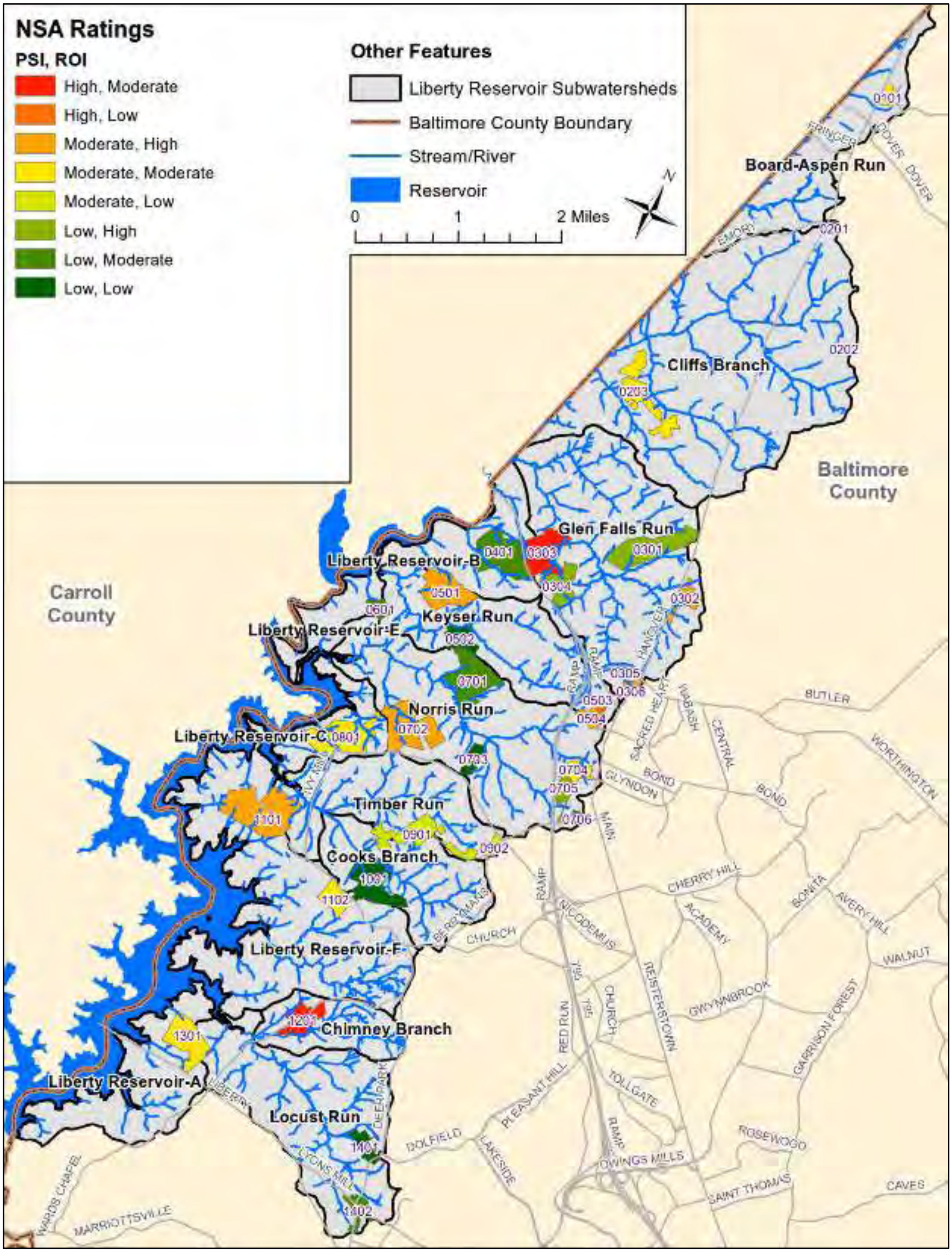

Figure 4-2: NSA Pollution Severity and Restoration Opportunity Indices in the Liberty Reservoir Watershed

4.2.3 General Findings

The following subsections describe the actions recommended based on evaluation of the NSAs. This includes an explanation of the methodologies and criteria used to evaluate the potential for recommended actions, as well as results expected if these actions were applied. Figures showing general locations of NSAs recommended for specific actions are included in each subsection. Due to the rural nature and low level of development in the Liberty Reservoir watershed, actions such as impervious retrofit, street sweeping, and trash management identified in other Small Watershed Action Plans (SWAPs) were not as prevalent as previously examined watersheds. Appendix B includes a summary of NSA data collected and recommended actions by individual neighborhoods. Calculations supporting estimates of results for recommended actions are included in Appendix C.

4.2.3.1 Downspout Disconnection

Rooftop runoff is managed via downspouts which are classified as either connected or disconnected. Directly connected downspouts extend underground, discharging directly to the storm drain system without treatment. Indirectly connected downspouts drain to impervious surfaces, such as paved driveways, sidewalks, or curb and gutter systems with little or no treatment. Disconnected downspouts allow rooftop runoff to infiltrate into the ground and enter streams through the groundwater system in a slower more natural fashion. Downspout disconnection is desirable because it decreases flow to local streams during storm events, helping prevent erosion and reducing pollutant loads to streams. Disconnection involves redirecting connected downspouts from the storm drain system or impervious areas onto pervious areas such as lawns. This requires a minimum of 15 feet of pervious area down gradient from the downspout for filtration to occur. Rain barrels and rain gardens are alternative disconnection options. Rain barrels can be used to store rooftop runoff for irrigation if there is limited pervious area for disconnection. Rain gardens are a disconnection option if several hundred square feet of lawn area is available down gradient of the downspout. In the event a downspout is directed onto an impervious area that drains to a pervious area, for example a driveway that slopes towards the lawn, the downspout was considered disconnected.

Downspout redirection is recommended for neighborhoods where at least 25% of downspouts are directly connected to storm drains or indirectly connected to impervious area with at least 15 feet of pervious area available down gradient of the connected downspout for redirection. Table 4-3 includes a summary of the number of neighborhoods recommended for downspout redirection and the acres of rooftop addressed if downspout redirection were implemented by subwatershed. Table 4-3 also lists the percent of total impervious rooftop area in each subwatershed that would be addressed if downspout redirection were implemented; total impervious rooftop area per subwatershed was calculated using 2008 buildings spatial data provided by Baltimore County OIT.

Table 4-3: Rooftop Acres Addressed by Downspout Redirection

Subwatershed	# of NSAs Recommended for Downspout Redirection*	Rooftop Acres Addressed	% of Subwatershed Rooftop Area Addressed
Board-Aspen Run	0	0.00	0.0%
Cliffs Branch	0	0.00	0.0%
Glen Falls Run	1	0.51	5.1%
Liberty Reservoir-B	0	0.00	0.0%
Keyser Run	1	0.96	15.2%
Liberty Reservoir-E	0	0.00	0.0%
Norris Run	2	2.84	18.5%
Liberty Reservoir-C	0	0.00	0.0%
Timber Run	0	0.00	0.0%
Cooks Branch	0	0.00	0.0%
Liberty Reservoir-F	0	0.00	0.0%
Chimney Branch	0	0.00	0.0%
Liberty Reservoir-A	0	0.00	0.0%
Locust Run	0	0.00	0.0%
Liberty Reservoir Total	***4***	***4.31***	***7.1%***

*If a neighborhood overlaps multiple subwatersheds, it is counted for each watershed it encompasses.

Figure 4-3 illustrates the location of neighborhoods recommended for downspout redirection. Out of the 32 neighborhoods assessed, 3 have the potential for downspout disconnection through redirection (one of the recommended NSAs intersects two subwatersheds). If implemented, the redirection could address approximately 7% of the total impervious rooftop area in the Liberty Reservoir watershed. Downspout disconnection was not evaluated at eight NSAs in the watershed as the majority of the downspouts in these neighborhoods could not be seen from the road due to bayscaping practices or houses set back from the road on large lots. In cases where downspouts were not visible due to rural conditions, it is unlikely that the downspouts could be connected to the storm drain system.

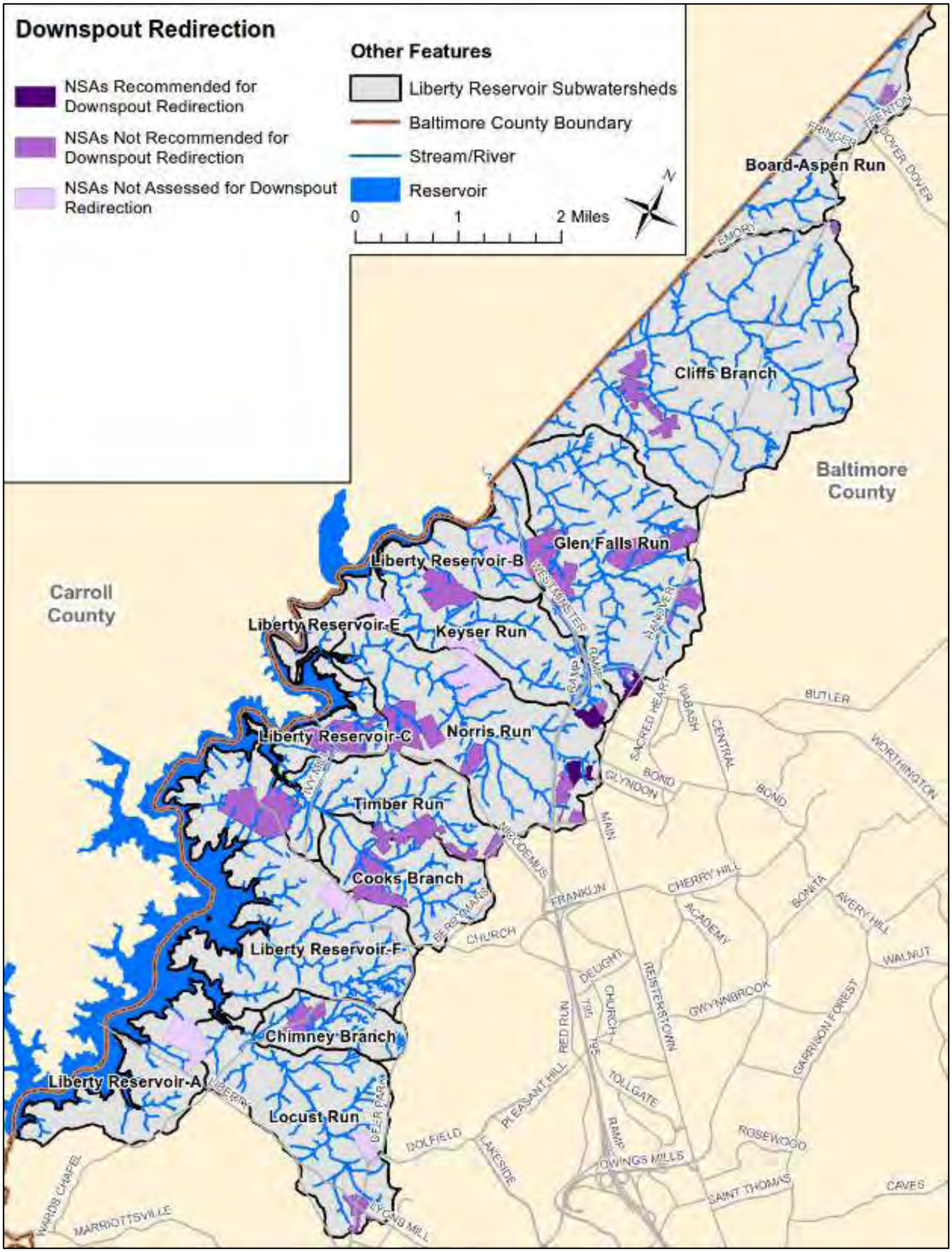

Figure 4-3: Neighborhoods Recommended for Downspout Disconnection

4.2.3.2 Bayscaping

Bayscaping refers to the use of plants native to the Chesapeake Bay watershed for landscaping. When plants are native to a region, they require less irrigation, fertilizers, and pesticides to maintain as compared to non-native or exotic plants. This results in fewer chemical pollutants and lawn maintenance requirements. Bayscaping is also beneficial to wildlife.

Typically, all neighborhoods could use more bayscaping; however, the benefits and feasibility of this action are limited by the space available for landscaping. Bayscaping was identified for implementation in neighborhoods where the lots were at least ¼ acre in size, where less than 10 percent of the lots were already landscaped, and where there was sufficient open grass area available for implementation. Table 4-4 includes a summary by subwatershed of the number of neighborhoods recommended for bayscaping based on these criteria and the area of available lawn addressed if this action were initiated. If a neighborhood overlaps more than one subwatershed, the neighborhood is counted within each watershed it encompasses. Table 4-4 also lists the percent of the total subwatershed area that would be addressed by implementing bayscaping in the recommended neighborhoods.

Table 4-4: Acres of Land Addressed by Bayscaping

Subwatershed	# of NSAs Recommended for Bayscaping*	Acres of Land Addressed	% of Subwatershed Area Addressed
Board-Aspen Run	1	12.2	1.6%
Cliffs Branch	3	55.4	1.8%
Glen Falls Run	6	181.6	8.8%
Liberty Reservoir-B	3	44.8	7.0%
Keyser Run	6	57.1	20.4%
Liberty Reservoir-E	1	7.2	0.7%
Norris Run	10	132.2	7.4%
Liberty Reservoir-C	2	59.4	15.2%
Timber Run	5	82.1	8.8%
Cooks Branch	3	68.8	8.8%
Liberty Reservoir-F	3	115.4	5.7%
Chimney Branch	1	35.4	8.1%
Liberty Reservoir-A	1	50.5	6.4%
Locust Run	3	40.2	2.8%
Liberty Reservoir Total	***48***	***942.2***	***5.7%***

*If a neighborhood overlaps multiple subwatersheds, it is counted for each watershed it encompasses.

Figure 4-4 illustrates the location of neighborhoods recommended for bayscaping. All of the 32 neighborhoods assessed met the criteria and were recommended for bayscaping. Many of the homes within the watershed have large lots and high percentages of lawn. Table 4-4 shows that approximately 942 acres or 5.7% of the total watershed could be addressed through bayscaping.

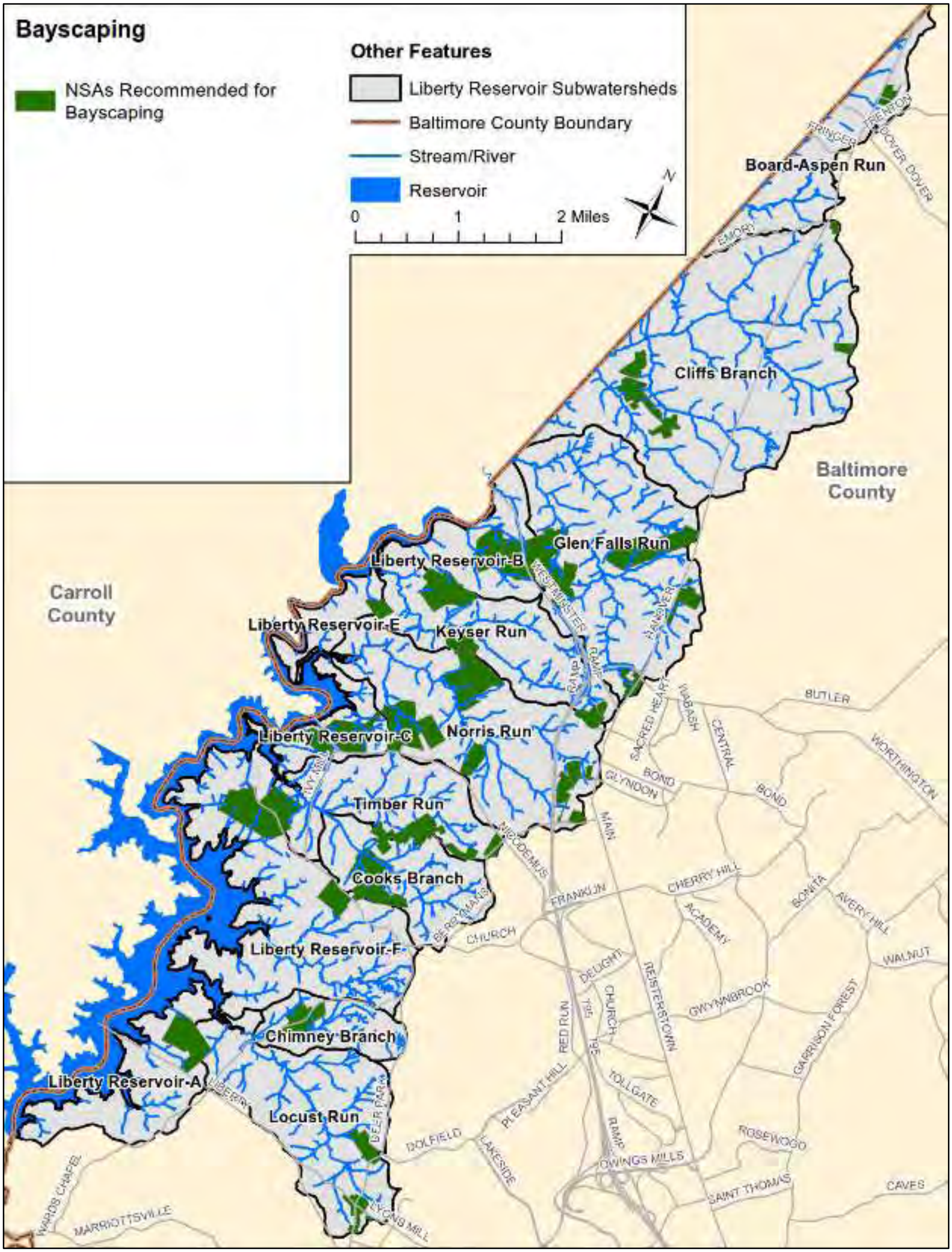

Figure 4-4: Neighborhoods Recommended for Bayscaping

4.2.3.3 Fertilizer Reduction and Education

Lawn maintenance activities often involve over-fertilization, poor pest-management, and over-watering. Lawns with a dense, uniform grass cover or signs designating application of lawn chemicals indicate high lawn maintenance activities. The result is often polluted stormwater runoff that drains to local streams. Neighborhood lawn care assessment was conducted in the spring.

Neighborhoods where 20 percent or more of the homes employ high lawn maintenance practices are identified for fertilizer reduction and education programs. Table 4-5 summarizes the total number of neighborhoods identified for fertilizer reduction and the acres of lawn addressed if this were implemented. The acres of lawn addressed are based on the percentage of high maintenance lawns present in each neighborhood for which fertilizer reduction is identified. The area treated in each neighborhood is based on the amount of lawn area. The average percentage of grass cover on each lot is estimated during the NSA, as well as the percentage of high maintenance lawns in the neighborhood area.

Table 4-5: Acres of Lawn Addressed by Fertilizer Reduction

Subwatershed	# of NSAs Recommended for Fertilizer Reduction*	Acres of Land Addressed	% of Subwatershed Area Addressed
Board-Aspen Run	0	0.0	0.00%
Cliffs Branch	1	23.1	0.73%
Glen Falls Run	1	22.8	1.11%
Liberty Reservoir-B	1	6.7	1.04%
Keyser Run	1	0.9	0.30%
Liberty Reservoir-E	0	0.0	0.00%
Norris Run	1	18.9	1.06%
Liberty Reservoir-C	1	0.5	0.13%
Timber Run	2	21.0	2.25%
Cooks Branch	1	12.2	1.55%
Liberty Reservoir-F	0	0.0	0.00%
Chimney Branch	0	0.0	0.00%
Liberty Reservoir-A	0	0.0	0.00%
Locust Run	0	0.0	0.00%
Liberty Reservoir Total	***9***	***105.9***	***0.64%***

* If a neighborhood overlaps multiple subwatersheds, it is counted for each subwatershed it encompasses

Of the 32 neighborhoods assessed, 5 were identified for fertilizer reduction based on high percentages of high maintenance lawn (three of the recommended NSAs intersects two or more subwatersheds). However, implementation of fertilizer reduction/education will only address approximately 0.6% of the total watershed. Many of the large, grass lawns were classified as medium maintenance. These neighborhoods may also be a significant target for fertilizer reduction and education. Figure 4-5 shows the neighborhoods in the Liberty Reservoir watershed with high lawn maintenance.

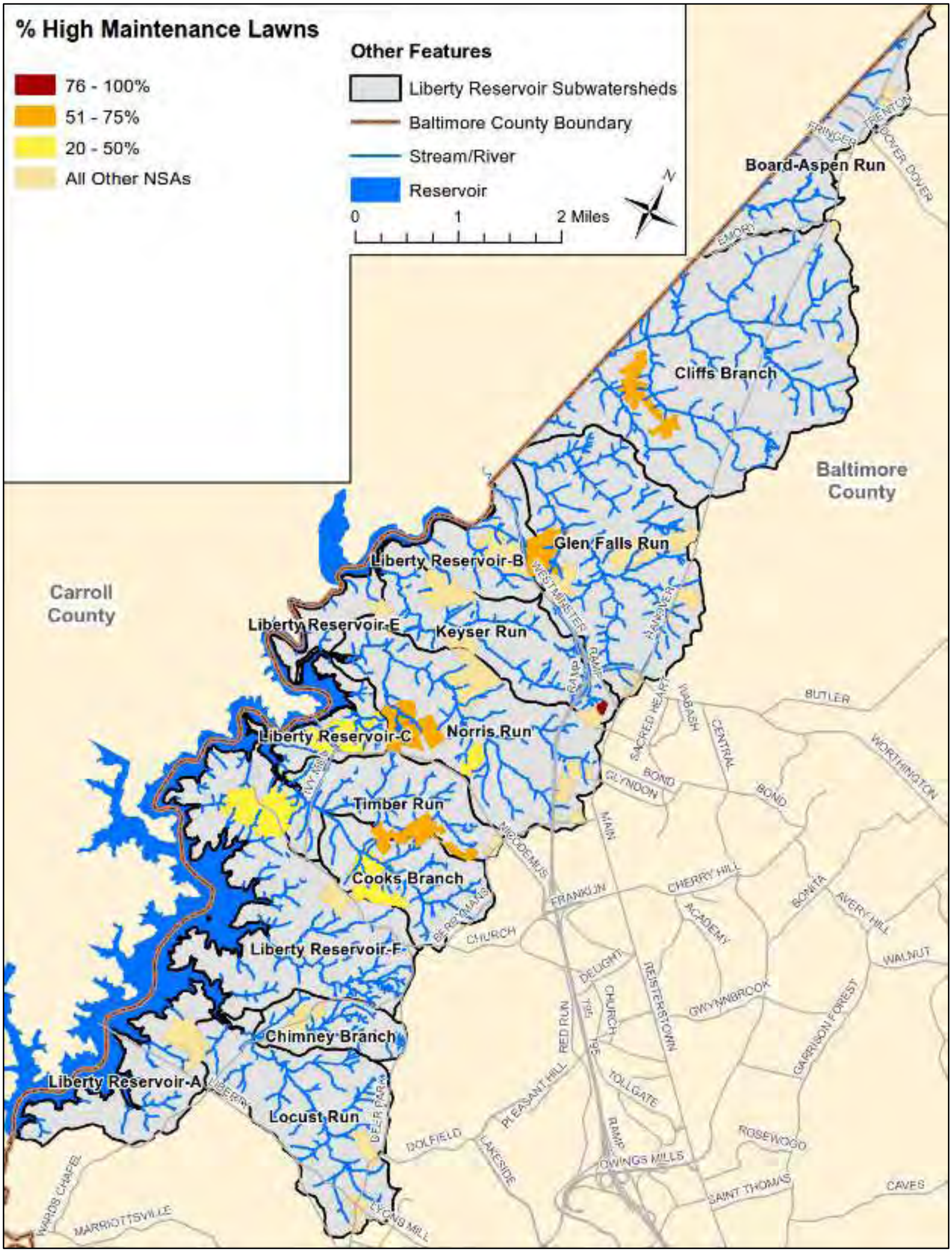

Figure 4-5: Percentage of High Maintenance Lawns in Neighborhoods

4.2.3.4 Storm Drain Marking

Of the assessed neighborhoods in the Liberty Reservoir watershed, 19 have a storm drain system with inlets. All 19 NSAs also have roads with curb and gutter systems that convey stormwater runoff quickly and directly to the stream system and ultimately to the Liberty Reservoir. The majority of the neighborhoods with inlets do not have storm drain markings nor indicate that the inlets eventually drain to the Liberty Reservoir. These markings are a way to educate residents that anything collecting along the curbs and gutters such as trash and lawn clippings (potential for nutrient pollution) will be washed away after a storm event and end up in the nearest stream and eventually the Liberty Reservoir.

Neighborhoods recommended for storm drain marking have storm drain systems with inlets appropriate for marking and where less than 10 percent of the existing inlets were already marked and legible. Table 4-6 includes a summary of the number of neighborhoods recommended for storm drain marking and the number of inlets addressed if this action were initiated by subwatershed. The number of inlets addressed is estimated based on the total number of inlets observed per NSA during the uplands assessments. Table 4-6 also lists the percent of the total neighborhood inlets in each subwatershed that would be addressed if storm drain marking was implemented in the recommended neighborhoods. This value was calculated based on the total inlets observed in neighborhoods assessed in the Liberty Reservoir watershed during the uplands assessment.

Table 4-6: Number of Inlets Addressed by Storm Drain Marking

Subwatershed	# of NSAs Recommended for Storm Drain Marking*	Approximate # of Inlets Addressed**	% of Inlets in Subwatershed Addressed
Board-Aspen Run	0	0	0.0%
Cliffs Branch	0	0	0.0%
Glen Falls Run	4	26	72.2%
Liberty Reservoir-B	3	10	100.0%
Keyser Run	2	7	23.3%
Liberty Reservoir-E	0	0	0.0%
Norris Run	3	11	15.1%
Liberty Reservoir-C	1	0	0.0%
Timber Run	3	5	19.2%
Cooks Branch	0	0	0.0%
Liberty Reservoir-F	1	14	93.3%
Chimney Branch	0	0	0.0%
Liberty Reservoir-A	1	4	100.0%
Locust Run	1	1	100.0%
Liberty Reservoir Total	***19***	***78***	***30.6%***

*If a neighborhood overlaps multiple subwatersheds, it is counted for each subwatershed it encompasses
**based on the total number of inlets observed in neighborhoods during the upland assessments

Of the 32 neighborhoods assessed, 11 (34%) met the criteria for storm drain marking. Figure 4-6 shows the neighborhoods in the Liberty Reservoir watershed recommended for storm drain marking.

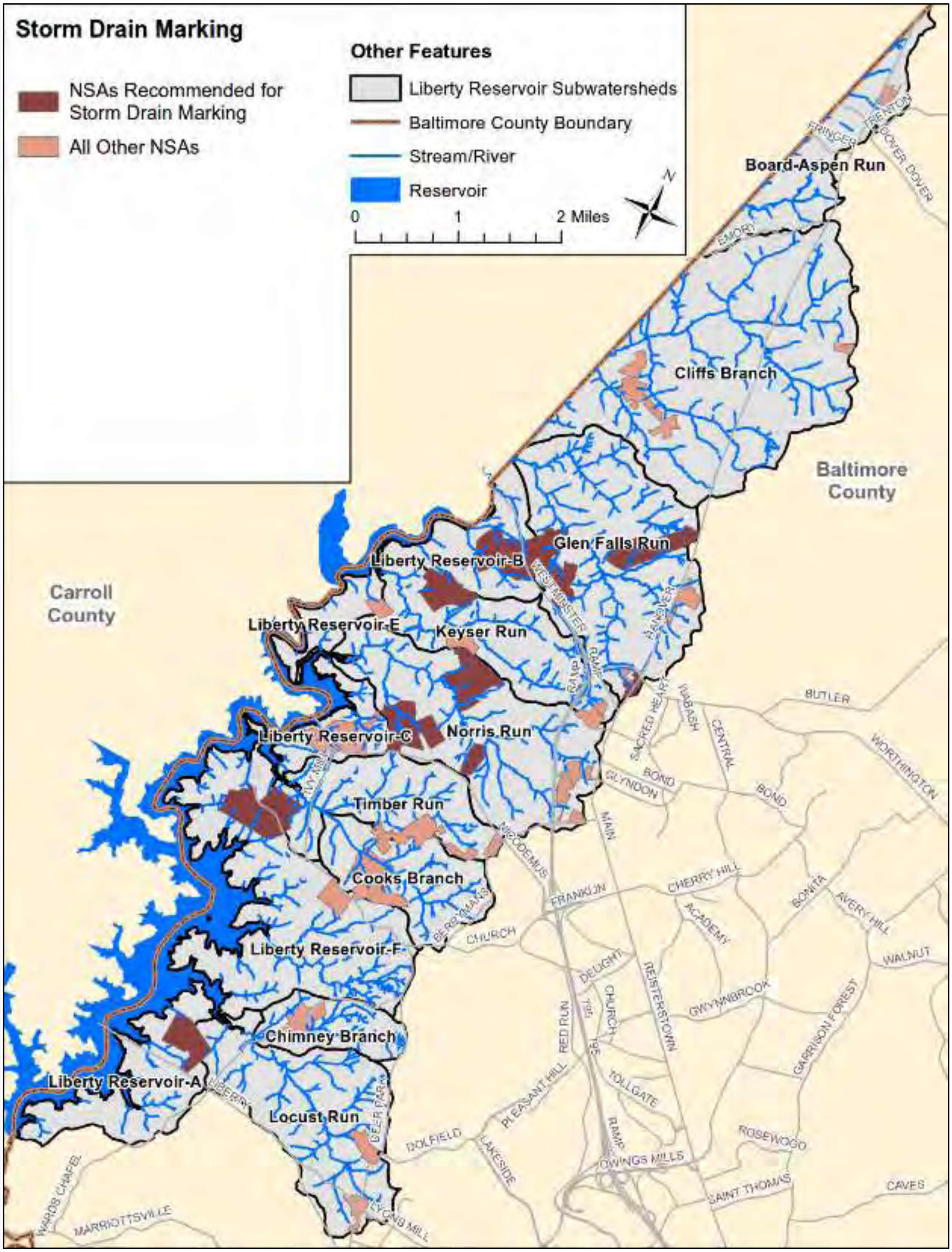

Figure 4-6: Neighborhoods Recommended for Storm Drain Marking

4.2.3.5 Street Trees and Shade Trees

Street trees and shade trees are not only an asset to a neighborhood aesthetically, but they also provide air and water quality improvement as they intercept precipitation with their leaves and absorb precipitation and nutrients through their root systems. Infiltration of precipitation through leaves or the root systems slows surface flow rates and provides some treatment before storm water reaches the stream system.

The criteria for recommending street trees includes neighborhoods with a minimum of four feet of green space between the sidewalk and curb with less than 75% of these areas already having trees. Only six assessed neighborhoods had sidewalks, and none of them met the criteria for street trees. Open space shade trees were recommended for open pervious areas in neighborhoods where the space had no apparent current use. The number of open space shade trees was estimated based on spacing of approximately 100 trees per acre for larger areas. The estimate for open space trees plantings are based on the Baltimore County Policy and Guidelines for Community Tree Planting Projects (Balt Co, 2013). Table 4-7 shows a summary of the number of neighborhoods recommended for shade tree planting and the number of shade trees proposed per subwatershed.

Table 4-7: Open Space Shade Tree Potential by Subwatershed

Subwatershed	# of NSAs Recommended for Shade Trees*	# of Shade Trees that Could be Planted
Board-Aspen Run	0	0
Cliffs Branch	0	0
Glen Falls Run	0	0
Liberty Reservoir-B	0	0
Keyser Run	0	0
Liberty Reservoir-E	0	0
Norris Run	0	0
Liberty Reservoir-C	0	0
Timber Run	2	30
Cooks Branch	1	17
Liberty Reservoir-F	1	3
Chimney Branch	0	0
Liberty Reservoir-A	0	0
Locust Run	0	0
Liberty Reservoir Total	***4***	***50***

*If a neighborhood overlaps multiple subwatersheds, it is counted for each subwatershed it encompasses

Figure 4-7 illustrates the location of neighborhoods where shade trees could be planted. Out of the 32 neighborhoods assessed, 2 neighborhoods (6%) met the criteria and were recommended for shade trees.

No NSAs were recommended for street trees. Based on the 32 neighborhoods assessed, 50 shade trees were estimated for neighborhoods within the Liberty Reservoir watershed.

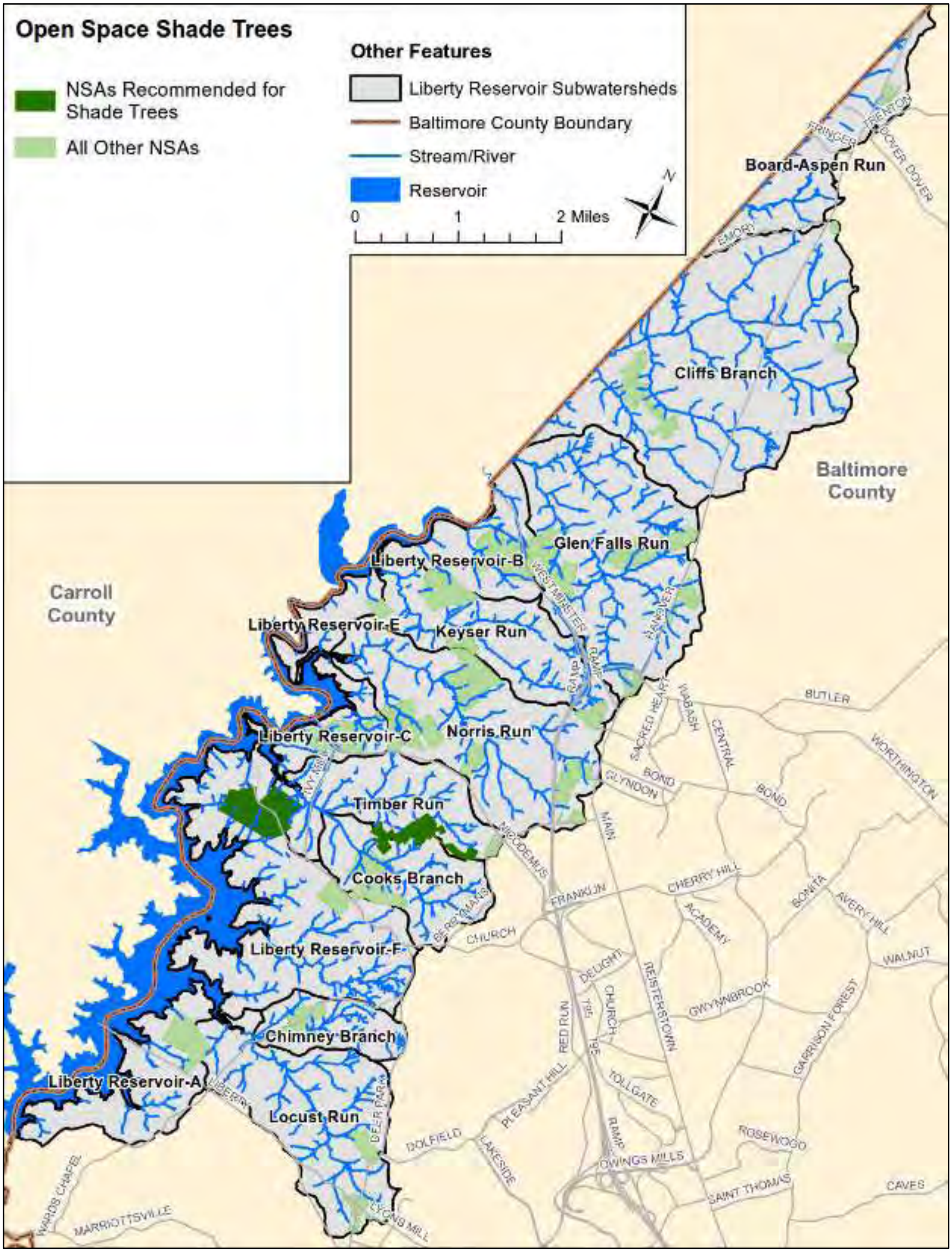

Figure 4-7: Neighborhoods Recommended for Shade Tree Planting

4.2.3.6 Lot Canopy Improvement

Increasing lot canopy is an effective way of reducing runoff and peak flows, improving filtration and water quality, and increasing shaded areas to reduce stream temperatures from excessive solar heating. Reforestation works with bayscaping and rain gardens to improve runoff infiltration and provide terrestrial habitat. Reforestation of stream buffers are especially important for maintaining healthy streams as roots stabilize banks, leaves contribute to the stream's food web, and trees also help reduce nutrient loading to downstream waters.

Lot canopy improvement was recommended for neighborhoods where existing canopy coverage was on average less than 40% of the lot. Table 4-8 summarizes the neighborhoods identified for lot canopy improvement in each subwatershed and the estimated acres of land addressed. It also shows the percentage of the total watershed area addressed through the implementation of lot canopy improvement. Pervious lot area is found by taking the total acreage in each neighborhood and subtracting out the acres of impervious roadway and buildings. This area is multiplied by the difference in percent between the recommended 40% and the existing percentage of canopy cover estimated during the NSA. NSAs recommended that encompass multiple subwatersheds were counted in each corresponding subwatershed; however, the total acres of land were determined based on the proportion of NSA within each subwatershed.

Table 4-8: Acres of Land Addressed by Lot Canopy Improvement

Subwatershed	# of NSAs Recommended for Canopy Improvement*	Acres of Land Addressed	% of Subwatershed Area Addressed
Board-Aspen Run	1	5.5	0.72%
Cliffs Branch	3	17.6	0.56%
Glen Falls Run	6	66.7	3.24%
Liberty Reservoir-B	2	11.0	1.73%
Keyser Run	3	18.8	6.73%
Liberty Reservoir-E	1	2.0	0.20%
Norris Run	6	37.2	2.08%
Liberty Reservoir-C	1	0.4	0.11%
Timber Run	4	33.8	3.63%
Cooks Branch	2	10.8	1.38%
Liberty Reservoir-F	2	41.3	2.05%
Chimney Branch	1	8.2	1.87%
Liberty Reservoir-A	1	18.1	2.31%
Locust Run	2	12.5	0.88%
Liberty Reservoir Total	***35***	***284.1***	***1.73%***

*If a neighborhood overlaps multiple subwatersheds, it is counted for each subwatershed it encompasses

Of the 32 neighborhoods assessed, 24 (75%) were recommended for lot canopy improvement. Of those 24 recommended neighborhoods, 4 were also recommended for better stream buffer management due to encroachment. Enhancing stream buffers through reforestation in these NSAs will also increase the lot canopy. Figure 4-8 shows the NSAs recommended for lot canopy improvement in the Liberty Reservoir watershed.

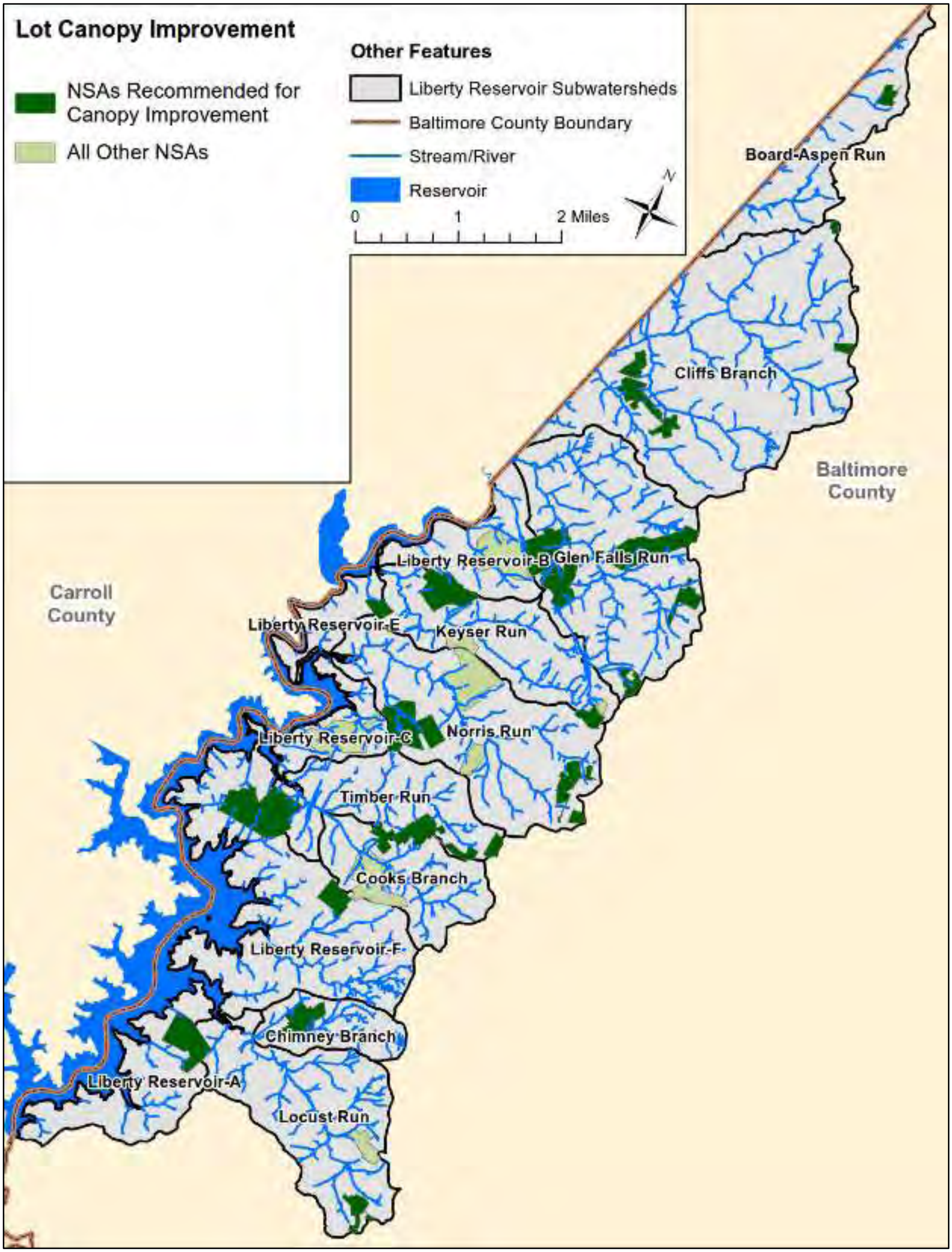

Figure 4-8: Neighborhoods Recommended for Lot Canopy Improvement

4.2.3.7 Stormwater Retrofits

Neighborhoods where sufficient open, green space is available down gradient from parking or roadways with no gutter systems are recommended for stormwater retrofit practice. The neighborhoods assessed either had adequate stormwater management facilities or did not have available open space to implement a stormwater retrofit.

4.2.3.8 Street Sweeping

Street sweeping helps remove trash, sediment, and other organic matter such as leaves and grass clippings from the curb and gutter system and prevents them from entering the storm drains and nearby streams. Street sweeping also reduces sediment and other pollutant loads such as oil and metals to the stream system. Excessive organic matter, sediment, and trash can clog streams and the storm drain system resulting in costly maintenance and stream health impairment. Also, the decay of an unbalanced amount of organic matter in a stream depletes the supply of dissolved oxygen, depriving aquatic life, including fish, of their oxygen demand. An aggressive street cleaning initiative can ease the effects of a curb and gutter storm drain system on receiving streams. The criteria for recommending street sweeping include neighborhoods where 25% or more of the curbs and gutters are covered with excessive trash, sediment, and/or organic matter. Of 32 neighborhoods assessed, none of the neighborhoods met the requirements for street sweeping.

4.2.3.9 Neighborhood Trash Management

Trash can be a major neighborhood pollutant. Neighborhoods where junk or trash was observed in 10% or more of yards are recommended for trash management initiatives. The uplands survey revealed that all of the neighborhoods were relatively free of trash and none were recommended for trash management education.

4.3 Hotspot Site Investigation (HSI)

Stormwater hotspots are areas that have potential to generate higher concentrations of stormwater pollutants than typically found in urban runoff and/or have a higher risk of spills, leaks, or illicit discharges due to the nature of their operations (CWP, 2005). These generally include commercial, industrial, municipal, or transport-related operations. Hotspots are either regulated or unregulated. Regulated hotspots are known sources of pollutants that abide by applicable federal or state laws (e.g., National Pollutant Discharge Elimination System (NPDES) permits). The nature of unregulated operations makes them likely potential pollutant sources. Stormwater pollutants generated as a result of hotspot operations depend on site-specific activities but typically include nutrients, hydrocarbons, metals, chloride, pesticides, bacteria, and trash.

Commercial hotspots include a range of businesses and activities but are normally grouped together in subwatersheds. Operations characteristic of commercial hotspots include waste or wash water generation, outdoor material storage, fuel handling, and auto/boat repair. Common commercial hotspots include but are not limited to auto repair shops, car dealers, car washes, parking facilities, gas stations, garden centers, construction equipment and building material lots, swimming pools, and restaurants. Industrial operations utilize, generate, handle, and/or store pollutants that can be washed off with stormwater, spilled, or mistakenly discharged into the storm drain. Many industrial hotspots are regulated under NPDES industrial discharge permits and include various manufacturing operations such as metal production, chemical manufacturing, and food processing. Municipal hotspots typically refer to local government operations such as solid waste, wastewater, road and vehicle maintenance, and yard waste. Like industrial operations, many municipal hotspots are subject to NPDES stormwater permits. Transport-related hotspots normally include areas of significant impervious cover and extensive private storm drain systems. Many are regulated and include uses such as airports, ports, highway construction, and trucking centers.

The purpose of the HSIs is to evaluate pollution potential from hotspot operations and identify potential restoration practices that may be necessary. The following subsections describe the methods used to identify and assess a sample of hotspots in the Liberty Reservoir watershed.

4.3.1 Assessment Protocol

The County preselected 16 hotspots for assessment; one site was split into three sites based on field observations and the distinct differences in land use. Two additional sites, a golf course and roller skating rink, were identified and included during the field assessment. A total of 20 hotspots were then evaluated.

One objective of the HSIs was to examine a variety of hotspot operations and select sites to represent common types of hotspots found in the watershed. HSIs were also focused on unregulated hotspots since access to regulated hotspots is often limited, and regulated hotspots are previously documented and known pollutant sources. Regulated hotspots are already subject to NPDES permit regulations which normally require strict effluent concentration limits and periodic monitoring. Obvious sources of pollution observed during the upland assessment were revisited for hotspot potential.

While hotspots have unique operations, drainage systems, and pollutant-related risks, stormwater quality problems can be characterized and evaluated by operations and activities common to most hotspots. Per the USSR manual, the HSI involved an evaluation of six common operations at each potential hotspot: vehicle operations, outdoor materials, waste management, physical plant, turf/landscaping, and stormwater infrastructure. The field team aimed to survey the entire property of each potential hotspot selected for an HSI to determine water quality impacts and restoration opportunities.

These six categories were used to standardize the HSI process and prioritize potential restoration efforts. Parameters evaluated within each operation category are described briefly below.

Vehicle Operations

Vehicle operations include maintenance, repair, recycling, fueling, washing, or long-term parking. The presence of any of these activities was noted for each site since they can be a major source of metals, oil and grease, and hydrocarbons. Outdoor activities including vehicle storage, repair, fueling, and washing were also noted as potential pollution sources. Connections between vehicle operations and the storm drain system are the main focus of this category. The following were noted during the HSI as potential pollution sources: vehicle spills/leakage, lack of runoff diversion methods from storage/repair areas, directly connected fueling areas, and direct discharges to the storm drain from vehicle washing.

Outdoor Materials

Stormwater quality issues result from improper handling or storage of outdoor materials at hotspots. Locations where materials were loaded or unloaded were examined to see if materials were uncovered and draining to a storm drain inlet. Storage areas were also evaluated for types of materials stored outdoors and their potential for entering the storm drain system. Uncovered materials and stained storage areas were used as indicators of poor outdoor storage practices and potential pollution sources. The field team also looked for improperly labeled storage containers, lack of secondary containment for liquids, and whether the storage area was directly or indirectly connected to the storm drain system. If any of these were observed, they were marked as potential pollution sources.

Waste Management

Every hotspot generates waste as a result of daily operations which can be potentially hazardous or a source of stormwater pollution depending on the type of waste and how it is stored. The field team noted the type of waste generated (e.g., hazardous, garbage, etc.) and the condition of dumpsters. Dumpsters with no cover or open lids, with leaks, damaged or in poor condition, and/or overflowing were noted as potential pollution sources. Dumpsters located near storm drain inlets and lacking runoff diversion methods were also recorded as potential pollution sources.

Physical Plant

Common physical plant practices include cleaning, maintaining, or repairing the building, outdoor work areas, and parking lots. These activities can be a source of sediment, nutrients, paints, and solvents in stormwater runoff. For each hotspot, the condition around the building was evaluated. Staining or discoloration around the building, which is evidence that maintenance activities (e.g., painting, power-washing, resealing, etc.) discharge to storm drains, were noted as potential pollution sources. Similarly, parking lots that were stained, dirty, breaking up, or had excessive impervious cover were recorded as potential pollution sources. Downspouts connected to impervious surfaces or directly to the storm drain system were also recorded as pollution sources at a hotspot site. A stain leading to storm drains denoted poor cleaning practices (e.g., for construction activities).

Turf/Landscaping

Ground maintenance activities for turf/landscaped areas were also evaluated at hotspot sites. High turf management and improper irrigation practices were noted since they are potential sources of nutrient, fertilizer, and pesticide pollution. The field team also determined whether landscaped areas drained directly to storm drains or if organics (leaves, grass) accumulated on impervious surfaces. More than 20 percent of bare soil in turf/landscaped areas was flagged as a sediment pollution source.

Stormwater Infrastructure

If stormwater treatment practices were not present, this was flagged as a potential pollution source. Private storm drains were also evaluated for pollution and illicit connection potential. Storm drains with considerable amounts of sediment, organics, and/or trash were identified as potential pollution sources.

Recommended Actions

For each operation on the HSI field form, there is an observed pollution source box which was checked when there was clear evidence of pollution problems at the time of the investigation. After surveying the entire property and evaluating hotspot operations, one or more of the follow-up actions listed below may be recommended based on initial field observations:

- Refer for immediate enforcement
- Follow-up on-site inspection
- Test for illicit discharge
- Future education effort
- Check to see if hotspot is an NPDES non-filer
- On-site non-residential retrofit
- Pervious area restoration
- Schedule a review of stormwater pollution prevention plan

4.3.2 Summary of Sites Investigated

A total of 20 potential hotspot sites were investigated in the Liberty Reservoir watershed. The hotspot candidates included as part of the upland survey are listed in Table 4-9. All assessed hotspots were given an initial hotspot designation based on the severity of pollution potential observed in the field. Hotspots were categorized as either severe, confirmed, potential, or not a hotspot. Locations and initial hotspot status designations are shown in Figure 4-9. These hotspot candidates were selected as a representation of common types of hotspot operations throughout the watershed. While based on this sample assessment, the overall watershed strategy should also encompass all hotspot operations occurring in the watershed.

Throughout the Liberty Reservoir watershed, fifteen (15) commercial facilities, two (2) industrial facilities, one (1) transport-related facility, one (1) municipal facility, and one (1) golf course were investigated.

Table 4-9: Summary of Hotspot Sites Investigated in Liberty Reservoir Subwatersheds

Site ID	Subwatershed	Type	Category
HSI_S_0101	Board-Aspen Run	Roller Skating Rink	Commercial
HSI_S_0201	Cliffs Branch	Lawn Equipment Store	Commercial
HSI_S_0202	Cliffs Branch	Auto Repair Shop	Commercial
HSI_S_0203	Cliffs Branch	Propane Tank Shop	Commercial
HSI_S_0301	Glen Falls Run	Nursery	Commercial
HSI_S_0302	Glen Falls Run	Restaurant	Commercial
HSI_S_0303	Glen Falls Run	Agricultural Business	Industrial
HSI_S_0304	Glen Falls Run	Nursery	Commercial
HSI_S_0305	Glen Falls Run	Construction	Commercial
HSI_S_0306	Glen Falls Run	Parking Lot	Transport-Related
HSI_S_0307	Glen Falls Run	Lumber Mill and Shop	Commercial
HSI_S_0501	Keyser Run	Grocery Store	Commercial
HSI_S_0502	Keyser Run	Golf Course	Golf Course
HSI_S_0701	Norris Run	Landscaping	Commercial
HSI_S_0702	Norris Run	Utility Company	Industrial
HSI_S_0703	Norris Run	Highway Shop	Municipal
HSI_S_0901	Timber Run	Contractor	Commercial
HSI_S_1101	Liberty Reservoir-F	Nursery	Commercial
HSI_S_1102	Liberty Reservoir-F	Auto Repair Shop	Commercial
HSI_S_1401	Locust Run	RV Company	Commercial

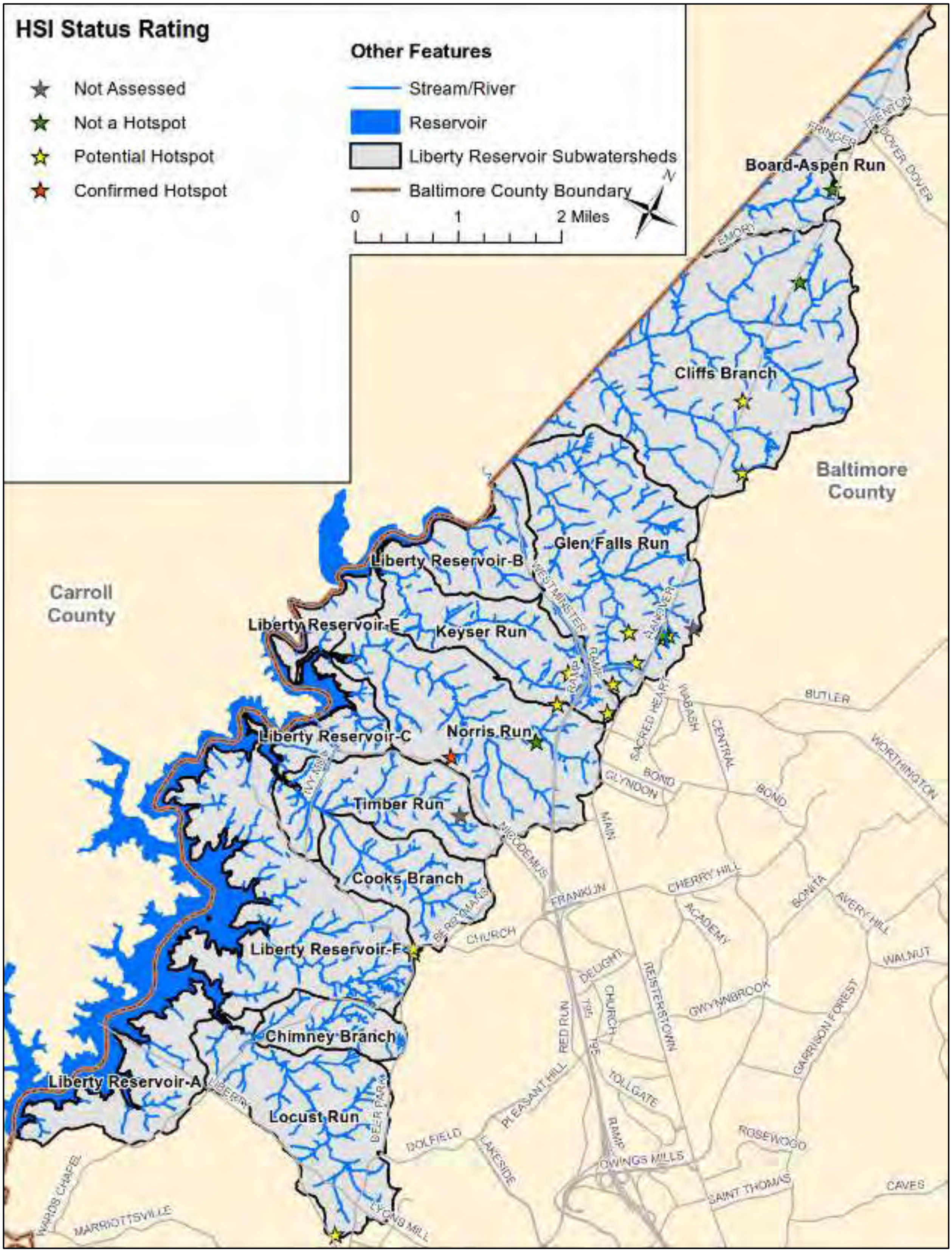

Figure 4-9: HSI Locations in the Liberty Reservoir Watershed

4.3.3 General Findings

A summary of HSI results is presented in Appendix B including hotspot status, category, pollution sources, and comments regarding hotspot observations. One confirmed hotspot was identified among the following sample of hotspot categories, transport-related, commercial, industrial, municipal, and golf course operations. Waste management (i.e., open dumpsters, dumpsters stored near stormwater inlets, trash/litter, etc.), vehicle operation (i.e., outdoor vehicle storage and repairs), and outdoor materials storage (i.e., uncovered loading/unloading and storage areas, staining/discoloration, etc.) were the most common potential pollutant sources observed in the watershed. A brief description of the various hotspot categories assessed and general findings are provided in the subsequent subsections. This includes a description of how the pollution potential for specific sites can be ranked within a specific category.

4.3.3.1 Commercial

There are fifteen commercial areas within the watershed, each with unique operations and pollution sources. Commercial hotspots were divided into categories based on characteristic operations and pollution sources: Auto-Related, Shopping Centers/Garden Centers, Construction Suppliers/Construction Services, Recreational Activities, and Restaurants.

<u>Auto-related</u>

There were two auto-related commercial establishments assessed in the Liberty Reservoir watershed. Both establishments were auto repair shops. The most common sources of stormwater pollution from this category of hotspots include vehicle operations, outdoor materials, waste management, and physical plant. Specifically for these two sites, vehicles operations and outdoor vehicle storage were the most common potential pollutant sources. Any of these activities can contribute potentially hazardous pollution to the storm drain system if proper housekeeping is not performed or if impervious surfaces lack diversions or treatment for stormwater runoff. It is also common for impervious surfaces (parking lots) at these types of hotspots to be stained as a result of vehicle operations or outdoor material storage which can also result in pollutants being transported by stormwater runoff. Some staining was observed at one of these sites (see Figure 4-10). The main recommended action for these types of operations is to include in future education efforts explaining proper waste management, ensure an adequate buffer or diversion methods from stream/storm drain systems, and incorporate treatment of stormwater runoff where possible.

Figure 4-10: No asphalt staining observed at one auto site (Left), while some asphalt staining was observed at the other site (Right)

Shopping Centers/ Garden Centers

There were several commercial shopping center areas within the watershed, including nurseries/garden centers, a grocery store, lawn equipment store, RV company, and propane tank shop. The most common potential pollutant sources came from outdoor material storage and waste management, ranging from stored materials lacking cover to uncovered or damaged dumpsters. Dumpsters are often located on impervious surfaces at shopping centers and if in poor condition, staining or leaks can contribute pollutants directly into the storm drain system or nearby stream. There is also potential for wind or rain to carry trash from uncovered or overflowing dumpsters to the storm drain or stream system (see Figure 4-11).


Figure 4-11: Potential pollution sources from improper waste management (Left) and liquid storage spill (Right)

Commercial areas sometimes have outdoor shopping or stockpile areas where materials are stored outside. Similar to the discussion above, if materials are uncovered and on impervious surfaces, runoff from these areas can go directly into the storm drain system along with certain pollutants depending on the type of materials. Some storage observed in Liberty Reservoir was done on wooden pallets allowing stormwater to flow under stored materials (See Figure 4-12).


Figure 4-12: Uncovered stockpile located near inlet in gravel parking lot is a potential pollution source (Left) and proper storage of outdoor materials on pallets (Right)

Construction Suppliers/Construction Services

Three commercial properties within the Liberty Reservoir watershed handled bulk inventory construction and landscaping supplies and services, including a landscaping business, lumberyard, and construction company. Pollution sources for these facilities often come from storage of outdoor materials and waste management. Vehicle operations may also contribute to pollution sources. The most common pollutant sources for these facilities were vehicle operations, outside storage, and physical plant that may be contributors to sediment accumulation around these sites. Future education was recommended to improve waste management and lawn care and increase bayscaping (Figure 4-13). Runoff from these areas can go directly into the storm drain system along with certain pollutants depending on the type of materials (Figure 4-14).

Figure 4-13: Future education efforts recommended to improve trash management and lawn care practices

Figure 4-14: Sediment accumulation on pavement and around storm drain

Recreational Activities

There were a couple of commercial recreational facilities in the watershed, including a roller skating rink and a golf course. These facilities are often prone to pollution from waste management and physical plant sources. In the Liberty Reservoir watershed, specific sources of potential pollution were lack of a stream buffer and downspouts directly connected to impervious surfaces (Figure 4-15). Both facilities have the potential for Stormwater Management (SWM) retrofits. The golf course currently has a pond that could be converted into a treatment pond while the skating rink has available space to install a SWM facility to treat the parking lot (Figure 4-16).

Figure 4-15: Lack of a buffer around stream (Left) and Downspouts Connected to Impervious Surface (Right)

Figure 4-16: Potential SWM retrofit opportunities

Restaurants

Commercial restaurant sites generally consist of parking area outside the restaurant facility with waste management practices located on site. Like shopping centers, impervious cover at restaurants can become deteriorated or stained, leading to sediment or nutrient-laden runoff entering local storm drain systems (Figure 4-17). Other common problems were uncovered or leaking dumpsters. This site is recommended for future education efforts related to waste management and replacement of broken up pavement with gravel.

Figure 4-17: Broken-up pavement and overflowing/uncovered dumpsters

<u>Commercial Hotspot Summary</u>

Pollution potential from commercial hotspots including auto-related facilities, shopping centers, construction suppliers, recreational facilities, and restaurants can be ranked as high, medium, or low based on the following example criteria:

- *High pollution potential*: Staining of impervious surfaces leading to storm drain inlets or stream; dumpsters in poor condition (leaking, overflowing, uncovered, next to storm drain or stream without diversion); improper disposal of hazardous materials or wash water; uncovered or lack of runoff diversion methods for repair/fueling areas or outdoor materials storage

- *Low pollution potential:* Proper disposal methods; good housekeeping (well maintained parking lot, waste management); stormwater management practices.

4.3.3.2 Transport-Related

Transport-related hotpots generally include large impervious areas and a significant amount of vehicle operations. They can also include waste management operations. These areas can be sources of potentially hazardous pollutants such as oil and grease from leaking vehicles and stained parking lot surfaces. Some can also be potential sources of trash/dumping and stormwater pollution from outdoor materials storage. These types of sites may be good candidates for future education efforts related to vehicle operations, outdoor materials storage, and waste management.

The one transport-related site, a parking lot servicing a commercial area, was located in the watershed. The parking lot was surrounded by open space that has the potential for tree plantings and a potential SWM retrofit to treat the parking lot (see Figure 4-18).

Figure 4-18: Potential location for SWM retrofit (Left) and open area available for tree plantings (Right)

Pollution potential from transport-related hotspots can be ranked as high, medium or low based on the following example criteria:

- High pollution potential: Staining of impervious surfaces leading to storm drain inlets or stream; dumpsters in poor condition (leaking, overflowing, uncovered, next to storm drain or stream without diversion); uncovered or lack of runoff diversion methods for repair/fueling areas or outdoor materials storage
- Low pollution potential: Proper disposal methods; good housekeeping (well maintained parking lot, waste management); stormwater management practices

4.3.3.3 Industrial

Industrial sites generally include manufacturing sites, maintenance yards for construction companies, and distribution centers. As discussed in Section 2.3.10, less than 0.1% of the watershed is zoned industrial. Despite the small percentage of cover, industrial areas have the potential to contribute a significant release of illicit pollutants into nearby storm sewers and surface waters.

Two industrial facilities were investigated in the Liberty Reservoir watershed: an agricultural business and utility company. The most common potential pollutant sources observed were related to vehicle operations and waste management. Specifically, vehicles were being stored at both sites and an uncovered fueling station was observed at one location. Another common potential pollutant source came from the presence of outside storage and dumpsters. Loose rubble, trash, and stockpiles were observed at the facilities. Stored improperly, outdoor materials can wash into waterways and loose trash can be washed or blown into drainage systems and streams. The utility company was not found to be a hotspot. The other industrial site is recommended for a follow-up site inspection, as significant sediment was observed on site and a thorough investigation of onsite stormwater management was not possible (Figure 4-19).

Figure 4-19: Uncovered outdoor storage area (Left) and significant sediment observed on pavement (Right)

Industrial Hotspot Summary

Pollution potential from industrial hotspots including construction companies and power plants can be ranked as high, medium or low based on the following example criteria:

- *High pollution potential*: Staining of impervious surfaces leading to storm drain inlets or stream; dumpsters in poor condition (leaking, overflowing, uncovered, next to storm drain or stream without diversion); improper disposal of hazardous materials or wash water; uncovered or lack of runoff diversion methods for repair/fueling areas or outdoor materials storage
- *Low pollution potential:* Proper disposal methods; good housekeeping (well maintained parking lot, waste management); stormwater management practices

4.3.3.4 Municipal Operations

Municipal properties tend to consist of storage yards, maintenance yards and fueling centers and these sites usually have large impervious areas. Municipal areas can also include offices and recreational facilities.

One municipal facility, a Baltimore County Highway Shop, was examined during the HSI assessments. The pollution sources observed were vehicle fueling and storage, outdoor storage, presence of garbage, and downspouts discharging to impervious surfaces. This facility had a large impervious lot with an uncovered fueling station, improper storage of outdoor materials, excess sediment available to leave the site, and overflowing dumpsters. Recommendations have been made for better trash management, improved stockpiling, and a review of the Stormwater Pollution Prevention Plan due to high volumes of sediment on impervious surfaces (see Figure 4-20). Stormwater management was observed (see Figure 4-21).

Figure 4-20: Improper waste management (Left) and significant sediment observed on pavement (Right)

Figure 4-21: Stormwater Management facility (Left) and super silt fence (Right) observed on site

Municipal Hotspot Summary

Pollution potential from municipal hotspots include public works maintenance yards, storage yards, and equipment storage and can be ranked as high, medium or low based on the following example criteria:

- *High pollution potential*: Staining of impervious surfaces leading to storm drain inlets or stream; improper disposal of hazardous materials or wash water; uncovered or lack of runoff diversion methods for repair/fueling areas or outdoor materials storage
- *Low pollution potential:* Proper disposal methods; good housekeeping (well maintained parking lot, waste management); stormwater management practices

4.4 Institutional Site Investigation (ISI)

The USSR manual does not treat institutional sites as a separate component of the uplands survey; instead, institutions can be assessed using HSI protocols. Consistent with recently completed county watershed studies, a modified version of the HSI field form was used to assess institutional sites since HSI protocols do not exactly match conditions encountered on institutional properties. The ISI method was first developed and implemented for the Upper Back River watershed study and was also used for the Tidal Back River, Middle River/Tidal Gunpowder, the Bear Creek/Old Road Bay, Middle Gwynn Falls, and Lock Raven North watershed studies. Institutions surveyed as part of this study include the following types of community-based facilities: schools, cemeteries, faith-based facilities, and a library. The following subsections describe the methods used to identify and evaluate pollution sources and restoration potential at institutional facilities.

4.4.1 Assessment Protocol

The County preselected 23 institutions for assessment. During the field assessment, one site was split into two to distinguish between different pollution sources at a school and public library, thus the final number of institutions investigated was 24. These sites were shown and labeled on field maps created for the upland assessments and on larger base maps showing the entire watershed. Institutions were surveyed as encountered in the field using these maps and a list of institutions as guidance. Unique ID numbers were assigned to ISIs using the classification scheme “ISI_S_0101”, where ‘S’ denotes the Liberty Reservoir watershed and the first two numbers correspond to a specific subwatershed. As previously described, subwatersheds were assigned the unique numbers summarized in Table 4-1 for the purposes of NSAs, HSIs, and ISIs. Institutional sites were then numbered sequentially within a particular subwatershed. For example, ISIs in Norris Run would be identified as 0701, 0702, 0703, etc.

The entire property of an institutional site was walked by the field team to collect necessary data and take photographs. Basic information was filled out first including type of institution, address, and ownership (public or private). Ownership is important as different approaches may be used to contact private versus public institutions. For example, a message may be received differently coming from the government as opposed to a non-profit group. Strategies for individual institutions will incorporate these different approaches. The ISI field form includes many of the pollution source categories used on the HSI form. Some of the restoration opportunities and recommended actions from the NSAs are also incorporated into the ISI. The focus of ISIs is to identify potential restoration opportunities, to educate the community, and to provide water quality benefits. The information collected for each of the pollution source and restoration categories are briefly described below.

Tree Planting

Potential tree planting locations at an ISI site were marked on aerial photographs while walking the property. After walking the entire site, the total number of trees that could be planted at the site was estimated based on 40-foot spacing between trees for narrow sites and based on an estimate of 100 trees per acre for larger open areas. More accurate numbers can be determined during the post-fieldwork desktop analysis after restoration opportunities have been selected and prioritized.

Exterior

The exterior category is similar to the physical plant category in the HSI, except it also includes restoration opportunities. The condition of the building(s) and parking lot(s) were noted. Stained, dirty, damaged, or breaking up surfaces were noted as potential pollution sources for both of these components. If no stormwater management was provided for impervious parking areas this was also considered as a potential pollution source. Exterior storm drain inlets were inspected for evidence of maintenance or wash water dumping and poor erosion/sediment control, cleaning, or material storage practices for construction activities. Any observations of staining, discoloration, or mop threads around a storm drain inlet indicated a potential pollution source as a result of these activities. Building downspouts that were directly connected to the storm drain system or indirectly connected to impervious surfaces were also recorded as potential pollution sources.

Potential restoration opportunities evaluated in the exterior category included impervious cover removal and downspout disconnection. Locations where excess impervious cover could be removed were marked on aerial field maps. Examples include unused or underutilized parking areas and abandoned athletic courts and foot paths.

Waste Management

Every institution generates waste as a result of daily operations, but unlike hotspots, it is typically just garbage. One exception to this could be health care facilities that have the potential to generate medical waste. The field team noted the type of waste generated (e.g., hazardous, garbage, medical, etc.) and the condition of dumpsters. Dumpsters with no cover or open lids, with leaks, damaged/in poor condition, and/or overflowing were noted as potential pollution sources. The field team also observed whether trash was present that could leave the site with wind or rain. Dumpsters located near storm drain inlets or lacking runoff diversion methods were also recorded as potential pollution sources.

Vehicle Operations

Most institutions did not have vehicle operations; however, several facilities did have one vehicle stored on site. A couple of facilities had multiple maintenance vehicles on site and one of those sites also had a fueling station. Vehicle operations include maintenance, repair, recycling, fueling, washing or long-term parking. The presence of any of these activities was noted since they can be a source of metals, oil and grease, and hydrocarbons. Outdoor activities including vehicle storage, repair, fueling, and washing were also noted as potential pollution sources. For the most part, it appeared that the institution likely only stored vehicles on-site.

Outdoor Materials

Materials such as mulch piles, storage drums, and de-icing salt are sometimes stored on institution grounds. Locations where materials were loaded or unloaded were examined to see if materials were uncovered and draining to a storm drain inlet. Storage areas were also evaluated for types of materials stored outdoors and their potential for entering the storm drain system. Uncovered materials and stained storage areas were used as indicators of poor outdoor storage practices and potential pollution sources.

Turf/Landscaping
The percentage of forest canopy, turf grass, landscaping, and bare soil covering the pervious area of a site was recorded on the field form. Sites with more than 20 percent of bare soil were noted as a potential source of sediment pollution. Ground maintenance activities for turf/landscaped areas were also evaluated. High turf management and improper irrigation practices (non-target/over-watering) were noted since they are potential pollution sources of nutrients, fertilizer, and pesticides. The field team also determined whether landscaped areas drained directly to storm drains or if organics (leaves, grass) accumulated on impervious surfaces. Evidence of buffer encroachment and whether buffers were adequately planted was also recorded for evaluating restoration potential.

Stormwater Infrastructure
The field team checked whether storm drains were marked and whether stormwater treatment practices were present. These were evaluated for potential pollution sources and restoration potential. In addition, field teams also noted opportunities for the installation of stormwater retrofits to treat existing impervious areas.

Recommended Actions
After walking the entire property and evaluating the categories discussed above, one or more of the follow-up actions listed below were recommended based on initial field observations:

- Tree planting
- Stormwater retrofit
- Downspout disconnection
- Impervious cover removal
- Trash management
- Storm drain marking
- Stream buffer improvement
- Education (e.g., lawn care, outdoor materials storage)

4.4.2 Summary of Sites Investigated
A total of 24 institutions were assessed throughout the Liberty Reservoir watershed. The number and type of institutions assessed within each subwatershed are summarized in Table 4-10. Several of the institutions overlap multiple subwatersheds. For this analysis, institutions which overlap watershed boundaries counted towards the subwatershed in which the majority of the area falls within. For example, Owings Mills Harvest Church of God encompasses portions of the Glen Falls Run and Keyser Run subwatersheds. Since the majority of the ISI area falls within the Glen Falls Run subwatershed, it was counted toward this subwatershed for analysis purposes. Figure 4-22 shows the distribution of the various types of institutions assessed throughout the watershed.

Table 4-10: Types of Institutions Assessed by Subwatershed

Subwatershed	Public Schools	Municipal	Faith-Based
Board-Aspen Run	-	-	1
Cliffs Branch	-	-	5
Glen Falls Run	-	-	3
Liberty Reservoir-B	-	-	-
Keyser Run	-	-	-
Liberty Reservoir-E	-	-	-
Norris Run	2	1	6
Liberty Reservoir-C	-	-	-
Timber Run	-	-	-
Cooks Branch	-	-	2
Liberty Reservoir-F	-	-	-
Chimney Branch	-	-	-
Liberty Reservoir-A	-	-	1
Locust Run	-	-	3
Liberty Reservoir Total	***2***	***1***	***21***

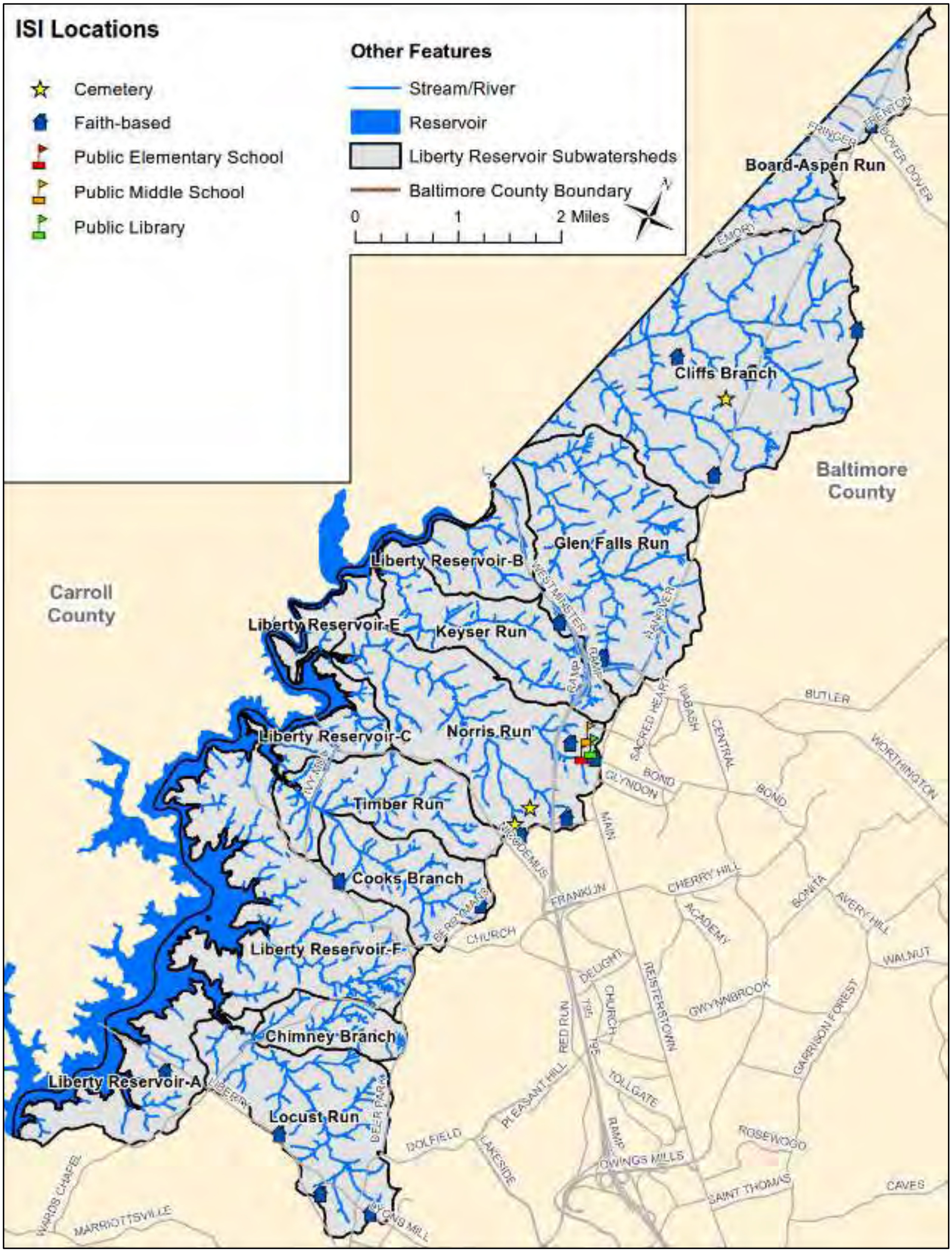

Figure 4-22: ISI Locations in the Liberty Reservoir Watershed

4.4.3 General Findings

The number and different types of recommended actions for ISIs are summarized in Table 4-11 by subwatershed. The most common potential pollution source observed at the ISI locations was untreated runoff from rooftops, parking lots, and other impervious surfaces. SWM facilities were recommended on multiple institutional sites to reduce pollution impacts from these locations.

Table 4-11: ISI Recommended Actions by Subwatersheds

Subwatershed	# of Trees	SW Retrofit	Downspout Disconnection	Impervious Cover Removal	Trash Management	Storm Drain Marking	Buffer Improvement	Education
Board-Aspen Run	28	1	1	0	0	0	0	0
Cliffs Branch	372	1	0	1	0	1	1	0
Glen Falls Run	136	0	0	0	0	0	2	1
Liberty Reservoir-B	0	0	0	0	0	0	0	0
Keyser Run	0	0	0	0	0	0	0	0
Liberty Reservoir-E	0	0	0	0	0	0	0	0
Norris Run	749	5	1	4	1	7	2	0
Liberty Reservoir-C	0	0	0	0	0	0	0	0
Timber Run	0	0	0	0	0	0	0	0
Cooks Branch	7	0	1	0	0	0	0	0
Liberty Reservoir-F	0	0	0	0	0	0	0	0
Chimney Branch	0	0	0	0	0	0	0	0
Liberty Reservoir-A	37	1	0	1	0	1	0	0
Locust Run	100	0	1	0	1	1	0	0
Liberty Reservoir Total	***1,429***	***8***	***4***	***6***	***2***	***10***	***5***	***1***

4.4.3.1 *Tree Planting*

It was estimated that a total of 1,429 trees could be planted at institutions located within the Liberty Reservoir watershed. Tree plantings were recommended for 17 out of the 24 institutions assessed. Tree planting sites were identified in the field and noted on field maps. The table above represents planning level estimates which would be refined through follow-up site investigations if a site is selected for a restoration/improvement project(s). Street trees and open space shade trees are not only an asset aesthetically but they also provide air and water quality improvement since they intercept precipitation with their leaves and can absorb precipitation and nutrients through their root systems. This infiltration of precipitation through leaves or the root systems slows flow input and provides some treatment before stormwater runoff reaches the stream system.

4.4.3.2 *Stormwater Retrofits*

As shown in Table 4-11, eight stormwater retrofits were recommended in four subwatersheds, while storm drain marking was recommended at ten sites. Downspout disconnection was recommended for three private institutions and one public institution where sufficient pervious area was available to redirect rooftop runoff. All of these actions present an opportunity to educate the community about the connection between the storm drain system, Liberty Reservoir watershed, and how their actions can impact or improve water quality.

Stormwater retrofits were recommended for eight private faith-based organizations. Stormwater retrofit opportunities included treating runoff from rooftops, parking lots, inlet retrofits, and conversion of existing SWM facilities. Sites where sufficient pervious area was available to treat a portion of the runoff from an impervious parking lot could implement infiltration or filtration practices such as bio-retention that incorporate vegetation and filter media through which stormwater infiltrates for pollutant removal prior to groundwater recharge or entering the stream system.

ISI_S_0705 is a site where impervious areas could potentially be treated by a bioretention facility. Bioretention facilities are nonlinear infiltration facilities that usually, but not always, receive concentrated flows. They incorporate landscaping plants that are planted in a special soil mixture, which promotes the removal of pollutants through filtration and the uptake of excess nutrients by the plants. As runoff filters through the soil mixture it infiltrates into the ground. The soil mixture is kept dry with an under drain system. The under drain either discharges into an existing storm drain system or daylights to a vegetated area.

At site ISI_S_0705, there is a potential opportunity to treat a cemetery road that currently drains to one of two inlets that daylight either into the lawn or the stream headwaters located approximately 50 feet from each other (see Figure 4-23). There appears to be space to treat at both sites.

Figure 4-23: Impervious area retrofit opportunity at ISI_S_0705 has potential to treat cemetary road and lawn before discharging into stream

Another facility that could potentially be treated by bioretention is site ISI_S_0702. This is a faith-based site that has portions of its parking lot drain to a low spot near an open area where sediment accumulates (Figure 4-24). It is possible that the broken up curb and gutter be removed from the down gradient edge of the parking lot and a bioretention facility be installed at the perimeter of the parking lot to treat runoff. The open space has an inlet that currently drains runoff to a nearby stream.

Figure 4-24: Parking lot retrofit opportunity at ISI_S_0702

Another facility where the parking lot could potentially be treated by bioswale stormwater retrofits is shown in Figure 4-25. Bioswales are similar to microbioretention in that stormwater treatment is provided with plantings in a special soil mixture; however, bioswales are linear facilities that usually receive sheet flow. ISI_S_1301 is a church and school where space could potentially be made for multiple bioswales by removing adjacent excess pavement and expanding medians. Stormwater currently sheet flows off of the parking lot and into an inlet. ISI_S_0101, ISI_S_0202, ISI_S_0702, ISI_S_0704, and ISI_S_0706 are all churches that have impervious areas from parking lots without curbs where runoff could be directed into bioswales or urban filter strips.

Figure 4-25: Parking lot retrofit opportunities at ISI_S_1301

ISI_S_0708 is a faith-based facility with an existing pond that collects runoff from a parking lot and playground. The pond does not appear to be a designed SWM facility based on the county database. The pond currently discharges into the headwaters of Norris Run. There is potential for conversion to a SWM facility at this site.

Figure 4-26: Existing pond at ISI_S_0708 with possible conversion to SWM facility

4.4.3.3 Downspout Disconnection

Downspout disconnection was a recommended action for three faith-based institutions and one elementary school. Institutional sites ISI_S_0101, ISI_S_1001, and ISI_S_1402 are churches with downspouts directly connected to the storm drain system. There is enough down gradient grass for the downspouts to be disconnected and discharged to a pervious area. The fourth facility, Franklin Elementary School, discharges to impervious areas. Again, there is adequate open, pervious area surrounding the facility for disconnection to take place.

4.4.3.4 Impervious Cover Removal

As discussed previously, impervious surfaces prevent precipitation from naturally infiltrating into the ground. Because runoff from impervious surfaces is often accelerated and concentrated when it reaches the storm drain and stream systems it can lead to stream erosion, habitat destruction, and water pollution. Removing unused or underutilized impervious surfaces will help increase pervious area and the watershed's capacity for infiltrating and treating stormwater runoff.

Impervious cover removal was a recommended action for six out of the 24 institutions investigated. It was a recommended action for sites where a considerable impervious area appeared to be abandoned or underutilized such as parking lots and athletic courts. It also included areas where impervious cover was not absolutely necessary and appeared to be damaged (patched or breaking up) such as areas on the side or behind buildings or areas between buildings and parking lots.

At site ISI_S_0204, an unused strip of pavement can be removed and planted as illustrated in Figure 4-27. Other examples where impervious cover can be removed are large unused impervious areas behind churches. At sites ISI_S_0701 and ISI_S_0703, broken up impervious walkways and parking lots were observed on the school properties. Much of the impervious area at the specified locations on each site can be removed and replaced with grass or bayscaping. Depending on how often the parking lot is used in ISI_S_0701, the broken up pavement may be replaced with either pervious pavers or grass. These sites are illustrated in Figure 4-28.


Figure 4-27: Examples of impervious cover removal opportunities at ISI_S_0204 (Left) and ISI_S_0704 (Right).


Figure 4-28: Examples of impervious cover removal opportunities at public schools ISI_S_0703 (Left) and ISI_S_0701 (Right).

4.4.3.5 *Trash Management*

Trash management is an area in need of improvement throughout various areas of the watershed, including institutions. A total of two private institution sites were recommended for trash management action. Waste management education is recommended to address leaking dumpsters, open or uncovered dumpsters where trash can leave the site, and dumpster placement near storm drain inlets or streams. For example, at ISI_S_0702, the dumpster lid has been left open and trash was left around the dumpster (Figure 4-29). Some trash was also observed in the lawn around the building. At site ISI_S_1402, several trash cans were overflowing and uncovered. Trash at both of these sites has the potential to be carried off-site by wind or rain.

Figure 4-29: Trash Management Opportunities at ISI_S_0702 (Left) and ISI_S_1402 (Right)

4.4.3.6 *Storm Drain Marking*

Ten of the institutional sites were identified for storm drain marking: five faith-based, two cemeteries, two schools, and one library. All of the recommended sites possess storm drain inlets that are currently unmarked.

4.4.3.7 *Buffer Improvement*

Forested buffer areas along streams are important for improving water quality and flood mitigation since they can reduce surface runoff, stabilize stream banks (root systems), shade streams, remove pollutants such as nutrients and sediment from runoff, and provide habitat for various types of terrestrial and aquatic life including fish. Several institutions have streams that run through the property which is a potential opportunity for improving an inadequate stream buffer by introducing native vegetation and trees. Buffer improvement options, however, must be sensitive to property uses while striking a balance with protecting water resources. For example, a narrow buffer consisting of native vegetation might be an alternative to 50-foot wide, wooded buffers on either side.

Buffer improvement was identified as a recommended action for five out of the 24 institutions assessed. These five sites include three faith-based facilities and two public schools. School properties typically represent a unique opportunity to combine restoration projects with education. The public schools recommended for buffer improvement are ISI_S_0701 and ISI_S_0703. The removal of invasive shrubs/bushes and installment of buffer planting could be performed in conjunction with a stream cleaning and/or restoration project.

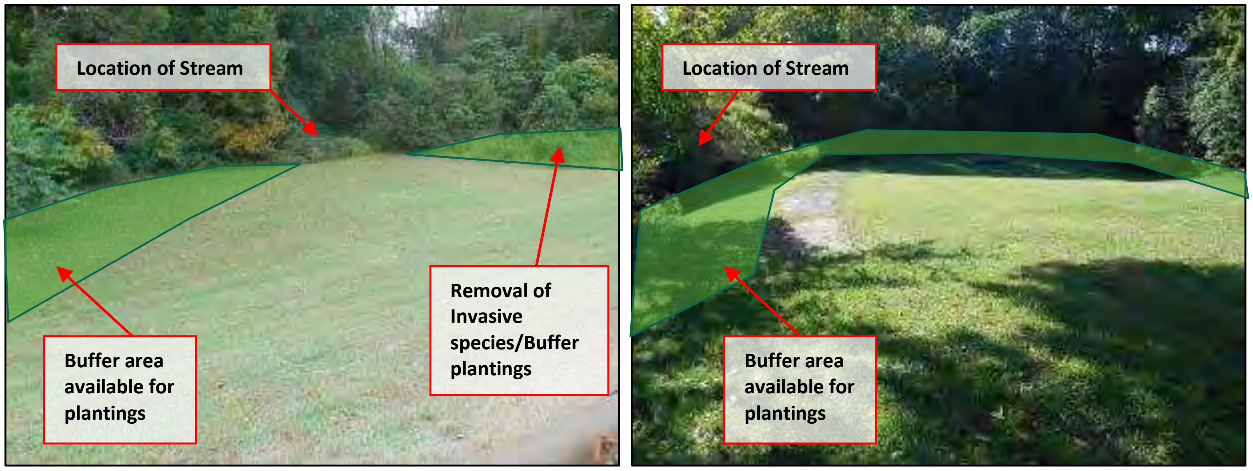

Figure 4-30: Buffer Improvement Opportunity at ISI_S_0701 (Left) and ISI_S_0703 (Right)

4.4.3.8 *Educational Efforts*

Educational efforts can have widespread benefits when implemented at institutions. The efforts can include waste management, property management (i.e. downspout disconnection, landscaping practices, invasive removal, etc.), proper material storage, and an overall increased awareness between community actions and water quality. Education efforts have been recommended for one institutional site.

4.5 Pervious Area Assessment (PAA)

The Pervious Area Assessment or PAA was used as a component of the USSR to identify and evaluate sites within the study area with potential for land reclamation, reforestation, or revegetation. The following subsections describe the methods used to identify and evaluate restoration potential of pervious areas.

4.5.1 Assessment Protocol

The areas being assessed were preselected by Baltimore County EPS. Although there are many open spaces in the Liberty Reservoir watershed, the majority of the assessment sites consist of county and state owned fields and parks, but public sites located with the Soldiers Delight Natural Environment Area (NEA) were not considered as the NEA maintains its own ecosystem restoration program. Additionally, two privately owned swim clubs and a privately owned service organization were also assessed. If additional tree planting is needed to obtain water quality standards other pervious areas will be investigated.

Unique ID numbers were assigned to PAAs using the classification scheme “PAA_S_0101”, where “S” denotes the Liberty Reservoir watershed and the first two digits correspond to a specific subwatershed. As previously shown in Table 4-1, each subwatershed was assigned a two digit number. The pervious areas were then numbered sequentially in the order they were surveyed within a particular subwatershed. For example, PAAs in Keyser Run would be identified as 0501, 0502, etc.

A new desktop analysis method for pervious area assessment, first utilized for the Loch Raven East SWAP, was also utilized for the Liberty Reservoir watershed. Using this method, open pervious areas were evaluated and rated using current aerial photography available through Baltimore County (2011). The parameters considered in the assessment are briefly described below. For each parameter, the PAA was evaluated, rated for restoration potential, and prioritized.

Stream Buffer

If the PAA site contained a stream with no forest buffer, it received a high score for reforestation potential. Adjacent properties were also examined for inadequate forest buffers (<100') that could potentially be expanded. As discussed in Section 2.2.7.2, stream buffers play an important role in improving water quality. For this analysis, a stream buffer with forest cover or natural vegetation was desired for at least 100 feet on either side to protect the stream environment and downstream conditions.

Length of Stream

If the PAA site contained a stream with no forest buffer, an approximate linear distance of stream that required a buffer and reforestation was recorded. The greater the length of stream in need of replanting and forest cover protection, the higher the priority the PAA was given for tree planting.

Proximity to Forest Interior

Forest interior is defined as forested areas located more than 500 feet from any forest edge. Many forest dwelling plants and animals benefit from having a continuous forest condition. It protects the ecosystem from invasive plant and animal species, which tend to thrive in edge habitats and disturbed conditions. Sites that have the potential to increase forest interior acreage were given the highest rating, while sites that have the potential to increase contiguous forests without the potential to expand interior forest were given a lower rating. Sites without existing continuous forest cover were given the lowest rating.

Exterior Forest Gap

An exterior forest gap is an unforested area located along the edge of a forest patch that would be enclosed by the outline of the outermost edge of the forest patch when connected by a line. In other words, if there is clearing located on the edge of the forest that extends into the forest that could be planted to create a continuous forest edge. Only exterior forest gaps with edges less than 500 feet apart were included. Similar to forest interior, it is beneficial to close forest gaps in order to increase the area of contiguous forest. Forest edges are subject to colonization pressure from invasive plants and non-native animals. Sites that have the potential to close exterior forest gaps were given a higher rating than those that did not.

Planting Area

The size of land available for planting was also used to score the restoration potential of a site. The larger the area available for planting, the higher the rating given to the site as the environmental benefit will be greater. Smaller planting sites are also valuable and present potential opportunities for community-based projects and were still rated.

Ownership

Restoration projects are typically easier to accomplish on publicly owned land than on privately owned land. While projects on privately owned land are sometimes possible, they require additional coordination with the landowner often making them more time consuming and costly.

Stormwater Retrofit Potential

In addition to rating the sites for restoration potential, the analysis also involved evaluating potential stormwater retrofit opportunities. Stormwater retrofits implement management controls to improve water quality by capturing, slowing, and treating runoff to receiving water bodies where previous practices do not exist. The type of stormwater retrofit selected is based on several considerations including available land, cost, ecological benefit, and specific objectives.

4.5.2 Summary of Sites Investigated

A total of nine pervious areas were assessed within the Liberty Reservoir watershed. Six of the sites were county or state owned, while three sites were privately owned swim clubs or service organizations. Potential planting sites ranged from 0.5 to 24 acres. Figure 4-31 shows the location and size of PAAs within the watershed.

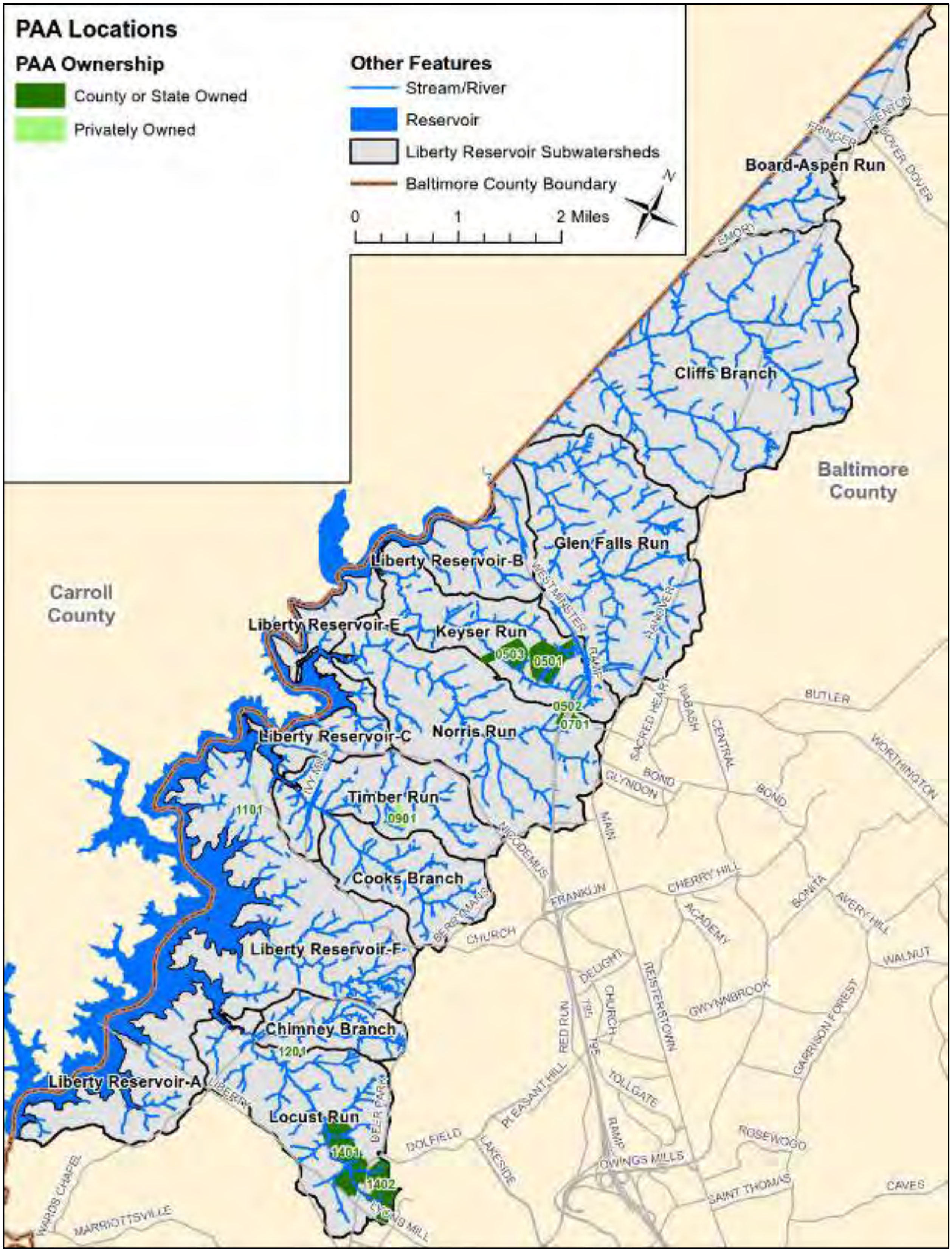

Figure 4-31: Pervious Area Assessment (PAA) Locations in Liberty Reservoir

4.5.3 General Findings

A summary of the selected PAAs and their results including area available for potential tree planning, presence of stream buffer, length of stream that can be planted, potential to expand forest interior acreage, presence of exterior forest gap, ownership, and stormwater retrofit potential is provided in Table 4-12.

Table 4-12: Liberty Reservoir PAA Summary

PAA	Planting Area (ac)	Stream Buffer Present	Length of Stream for Planting (linear ft.)	Expand Forest Interior	Exterior Forest Gap	Ownership	Restoration Score	SW Retrofit Potentia l
PAA_S_0501	12.5	Yes	1,500	No	Yes	Public	80	No
PAA_S_0502	n/a	No	n/a	No	No	Public	n/a	No
PAA_S_0503	24	Yes	570	No	Yes	Public	65	No
PAA_S_0701	0.5	No	n/a	No	Yes	Public	30	No
PAA_S_0901	1	No	n/a	No	No	Private	10	Yes
PAA_S_1101	2	No	n/a	No	No	Private	5	No
PAA_S_1201	0.5	No	n/a	No	Yes	Private	25	No
PAA_S_1401	24	Yes	400	No	Yes	Public	65	No
PAA_S_1402	3.5	No	n/a	No	Yes	Public	40	No

PAA_S_0501

Located off of Mitchell Drive in the Keyser Run subwatershed, PAA_S_0501 is the Reisterstown Regional Park owned and maintained by Baltimore County. The facility currently utilizes four storm water management facilities to treat its runoff. The site has approximately 1,500 feet of stream without adequate forest buffer. Additionally, the site has 3.5 acres of forest gap that can be planted in the southern portion of the parcel. An additional two acres of space is available west of the ball fields. Together, the planting sites expand 12.5 acres of forest but do not expand forest interior.

Figure 4-32: PAA_S_0501 has opportunity to plant in an insufficient stream buffer, increase existing forest, and close an exterior forest gap (photo)

PAA_S_0502

Located off of Cockeys Mill Road and straddling the Keyser Run and Norris Run subwatersheds, PAA_S_0502 is a narrow piece of land between I-795 southbound and a lumber/milling yard. The property is used as an easement for Baltimore Gas and Electric power lines. Due to the presence of the power lines, there is no potential for restoration and this site was not assessed further.

Figure 4-33: PAA_S_0502 is an easement for power lines and was not assessed for restoration opportunities

PAA_S_0503

Located off of Cockeys Mill Road in the Keyser Run subwatershed, PAA_S_0503, is a 49.5 acre lot owned by Baltimore County. There is approximately 24 acres of open space with the potential for planting depending on desired land use. The parcel is zoned agricultural and currently appears to be at least partially used for agricultural purposes. Further investigation would determine the extent of land being actively cultivated. If all of the open space is being used for crops, trees will likely not be planted on the parcel. This would give the area a low priority. If, however, there is open space that is not being cultivated than the parcel would be a high priority area due to the potential to minimize an exterior forest gap and expand the buffer along approximately 570 feet of stream.


Figure 4-34: PAA_S_0503 is a Baltimore County owned parcel that is partially farmed as seen from the view from Cockeys Mill Road. (Source, right: Google Map)

PAA_S_0701

Located in the Norris Run subwatershed, PAA_S_0701, is a 3.6 acre lot owned by Baltimore County located behind Bensmill Court in the Stone Mill development. There is approximately 0.5 acres of open space with potential to plant. This open space has the potential to minimize an exterior forest gap. While this site is located on public land, the small area available for planting makes the site a low priority.

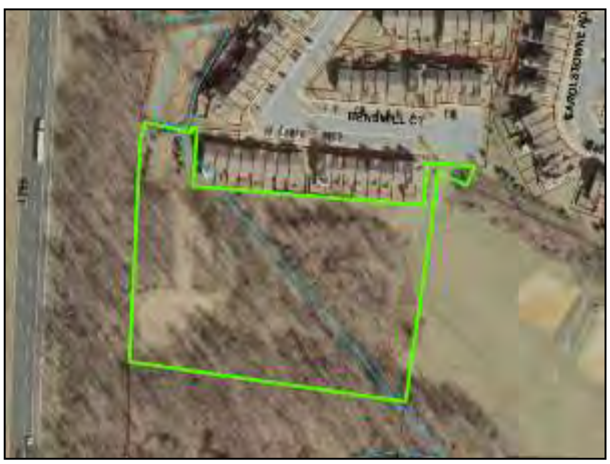


Figure 4-35: PAA_S_0701 is owned by Baltimore County and has the potential for tree planting in open space behind the Stone Mill development.

PAA_S_0901

Located in the Timber Run subwatershed off of Saffell Road, PAA_S_0901 is a 14.6 acre property privately owned by the Green Valley Swim Club. Approximately 4.55 acres of the property is already under a Forest Conservation Easement (represented as hatching in Figure 4-36). There is opportunity to plant approximately 1 additional acre of trees beyond the existing conservation easement to further expand the forested stream buffer. Plantings should be chosen with the intention to not block the line of sight from the building to the tennis courts. There are overhead power lines running across the mowed open space of the property, further limiting planting opportunities. There is also potential for storm water management retrofit to treat portions of the parking lot.

Figure 4-36: PAA_S_0901 is a privately owned parcel with potential for buffer expansion beyond the existing conservation easement and SWM retrofit

PAA_S_1101

Located off of Deer Park Road in the Liberty Reservoir-F subwatershed, PAA_S_1101 is a privately owned swim club in the neighborhood of Folly Quarter. The parcel has 2 acres of open space that is available for potential plantings. Proposed tree plantings would not expand interior forest or exterior forest gap; and therefore, the site is of low priority.

Figure 4-37: PAA_S_1101 is a privately owned swim club with potential for tree planting in the open space behind the swimming facility

PAA_S_1201

Located in the Chimney Branch subwatershed, PAA_S_1201 is an 8.1 acre parcel privately owned by the Knights of Columbus. The parcel is located off of Stang Road, east of Wards Chapel Road, and is bordered to the north by the Soldiers Delight Natural Environmental Area. There is 0.5 acres of open space located adjacent to the Soldiers Delight land that is potentially available for tree planting. This planting will minimize the existing exterior forest gap. Planting this area will also expand existing forest but will not expand interior forest land. There are no streams within the parcel limits and no opportunities for storm water retrofit.

Figure 4-38: PAA_S_1201 is located adjacent to the Soldiers Delight Natural Environment Area and has open space with potential for tree planting between the structures and the wood line

PAA_S_1401

Located off of Deer Park Road in the Locust Run subwatershed, PAA_S_1401 is the Under Armour Performance Center for the Baltimore Ravens. The parcel is owned by Baltimore County and currently has three storm water management facilities to treat runoff. The parcel is also bordered by the Soldiers Delight Natural Environmental Area to the north. There are 24 acres available for tree planting, which would expand existing forest and minimize exterior gaps. In addition, there is approximately 400 feet of stream on the property with inadequate forest buffer that has the potential for tree planting.

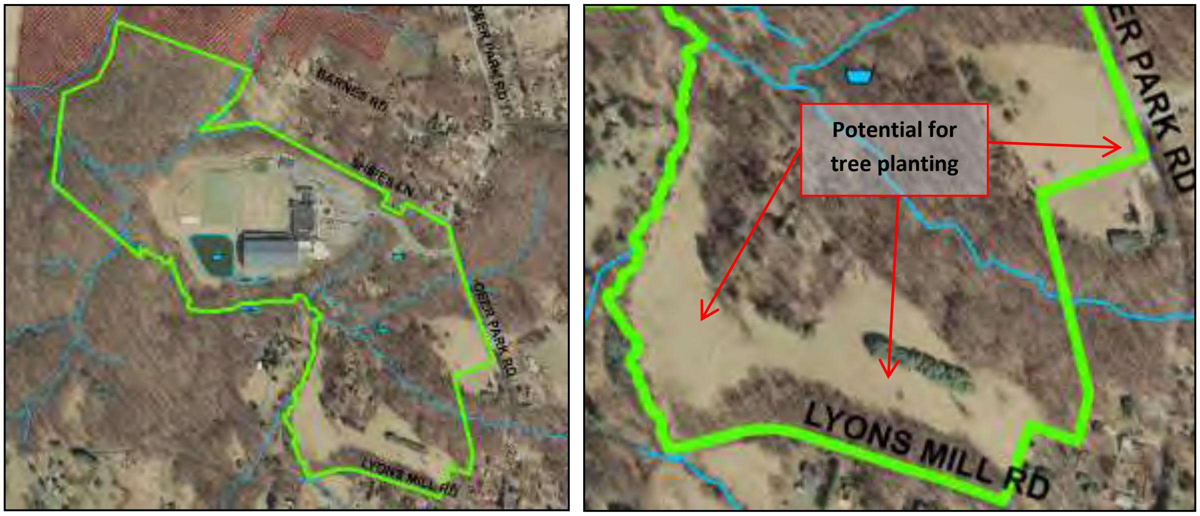

Figure 4-39: PAA_S_1401 is publicly owned and bordered by Soldiers Delight to the North. The site has potential for tree planting

PAA_S_1402

Located in the Locust Run subwatershed on the border of the Liberty Reservoir watershed with the Gwynns Falls watershed, PAA_S_1402 is the county managed Northwest Regional Park. The site currently treats its runoff with three existing storm water management facilities. Four open space locations on the site totally approximately 3.5 acres have the potential for tree planting. Three of these sites would expand continuous forest but not forest interior, and one of the sties would minimize an existing forest gap. The streams on this site already have adequate forest buffer. Therefore, this site is a low priority for restoration.

Figure 4-40: PAA_S_1402 is a county park with potential planting opportunities throughout the site

Prioritization of Tree Plantings on Pervious Areas

Each site was given a Restoration Score derived by a point system of the parameters discussed in Section 4.5.1. The maximum score is 100 (greatest restoration benefit), while the minimum score is 5. Restoration scores for Liberty Reservoir PAAs range from 5 to 80. The highest scores go to large, public lands with streams, while the lowest scores go to small, private land removed from streams and forested areas. To comply with the Chesapeake Bay Total Maximum Daily Load (TMDL), Baltimore County must plant trees in stream buffer areas to decrease nutrient and sediment transport to the waterways, making sites with streams a higher priority. Decreasing forest fragmentation is also paramount in protecting the populations of native species, including neo-tropical migrating birds. See Table 4-13 for prioritization results.

Table 4-13: Liberty Reservoir PAA Restoration Priority

PAA	Restoration Score	Priority
PAA_S_0501	80	High
PAA_S_0503	70	High
PAA_S_1401	65	Medium
PAA_S_1402	40	Low
PAA_S_0701	35	Low
PAA_S_1201	25	Low
PAA_S_0901	10	Low
PAA_S_1101	5	Low
PAA_S_0502	N/A	N/A

4.6 Other Upland Areas

4.6.1 Forested Land

The most prominent land use within the Liberty Reservoir watershed is forest (deciduous, evergreen, and mixed) making up 42% of the area or approximately 6,929 acres. Forested land was not included in the upland assessments but it has a large impact on stream health and water quality. Forest buffers along streams prevent pollution from entering receiving waters, stabilize stream banks, provide habitat and food for wildlife, and help keep water temperatures cool. The most beneficial management practice for forested lands is conservation, ensuring that the ecological advantages provided by forest and canopy are preserved.

4.6.2 Soldiers Delight

Soldiers Delight NEA is comprised of 1,900 acres of serpentine barren, which is the largest serpentine barren in the state. This area contains over 29 rare, threatened, or endangered plant species which are currently being threatened by an invasion of Virginia Pine. Maryland Department of Natural Resources (DNR) is actively removing the invasive species through controlled burns within the area (DNR, 2014a). The site includes seven miles of marked trails, a visitor's center, and various family-friendly activities. DNR has also implemented a deer management program at Soldiers Delight. The program includes expanding the annual managed hunting program to control the increasing deer population at sustainable levels, as the current levels threaten many of the rare, threatened, and endangered species found in the NEA. A significant portion, 1,296 acres or 68%, of Soldiers Delight NEA falls within the Liberty Reservoir watershed.

4.6.3 Camp Fretterd

Camp Fretterd is a 586 acre Maryland Army National Guard training facility, 98% of which is located within the Liberty Reservoir watershed. This facility encompasses approximately 4% of the Cliffs Branch subwatershed and 22% of the Glen Falls Run subwatershed with multiple stream segments running through the property. The facility is currently taking steps to insure proper stormwater management. The facility operates six stormwater management facilities, which treat approximately 35% of the impervious area on the property. While all vehicles are stored outdoors, each vehicle is stored with a drip pan to catch any leaks. In addition to fueling stations, the facility has fuel transport vehicles; these vehicles are stored outdoors within secondary containment berms, and no vehicles are washed onsite. Approximately 93% of the 5.9 miles of streams on the property have a 100 foot forest buffer, and practices are in place to minimize guard activities near waterways. The facility coordinates with DNR to manage the deer population on site. Approximately 2 acres have already been reforested by the facility and an approximate 5.4 acres are potentially available for future restoration.

4.6.4 Baltimore City Owned Reservoir Land

Baltimore City owns and manages land surrounding Liberty Reservoir in an effort to protect the drinking water supply for residents in Baltimore City and surrounding counties. This protected land accounts for approximately 2,105 acres within Liberty Reservoir watershed. This land was not included in the upland assessment but it has a large impact on water quality within the reservoir. Nearly all the land in this area is forest or wetlands, providing a buffer along the edge of the reservoir to decrease pollution from entering the waterbody.

CHAPTER 5: RESTORATION AND PRESERVATION OPTIONS

5.1 Introduction

This chapter presents an overview of the key management practice recommendations for the Liberty Reservoir watershed based on the information collected during both the office/desktop analysis and field assessments. Due to distinct differences in runoff characteristics among different land uses, (i.e. developed/residential and undeveloped/agricultural), the appropriate stormwater best management practice (BMP) will vary by land use. For that reason, the management practices recommended in this chapter are geared toward the rural nature of the Liberty Reservoir watershed, including residential, agricultural, and forested areas. The chapter is divided into five sections: Municipal Capital Programs; Municipal Management Programs; Volunteer Restoration Programs; Neighborhood, Business, and Institutional Initiatives; and Citizen Awareness Activities. The sections were outlined based on the entity controlling and performing the activities along with their funding and schedule requirements.

5.2 Municipal Capital Programs

Municipal capital programs are characterized as projects and purchases that Baltimore County can undertake in the short term to improve water quality in the Liberty Reservoir watershed.

5.2.1 Stormwater Management Upgrades

The application of stormwater management practices varies according to various physical characteristics such as impervious cover and land use makeup of the site or subwatershed. The most efficient method to augment stormwater treatment is to convert existing stormwater facilities to a design with greater pollutant removal capability, for example a dry detention pond to an extended detention pond or wetland. This is referred to as a stormwater pond conversion. If enough land is available, the greatest benefit would be to construct a new facility, designed with current state of the art technology, to reduce pollutants to the maximum extent practicable. However, a developed subwatershed seldom has sufficient open space. Instead there are options available to put treatment systems directly in the storm drain system. Many packaged systems are available through the retail market and are explained further below. Additional sites in alleys and adjacent to parking lots can offer treatment of large amounts of impervious surface. Also, new research in porous concrete and asphalt may offer the potential for additional reductions in impervious cover on public and private properties.

Most of the Liberty Reservoir watershed was developed prior to the passage of the Stormwater Act of 2007 in Maryland requiring more robust environmental site design. Stormwater retrofitting involves implementing stormwater BMPs and/or treatment devices in existing developed areas where previous practices did not exist or were ineffective to help improve water quality. Stormwater retrofits improve water quality by capturing and treating runoff before it reaches receiving water bodies. Retrofits target specific objectives depending on BMP type including stormwater quality, soil stabilization, stormwater flow control, and stream restoration. Several considerations must be taken into account to select appropriate stormwater treatment measures such as space requirements, cost, and community acceptance. Based on initial field and desktop evaluations, the following stormwater retrofit categories are recommended for addressing water quality issues in the Liberty Reservoir watershed through municipal capital programs: stormwater management conversion and retrofit, storm drain inlet and outfall retrofits, and public parking retrofits. Each of these categories is described briefly in the sections below.

5.2.1.1 *Stormwater Facility Conversion and Retrofit*

The majority of the Liberty Reservoir watershed is largely undeveloped consisting of agricultural cropland and forest. Many of the developed regions, were constructed prior to the Stormwater Act of 2007 and do not include stormwater management facilities to treat stormwater runoff. This produces an excellent opportunity to introduce new stormwater facilities to treat and manage runoff in developed areas.

Additionally, it is often observed that current stormwater management facilities can be converted to increase effectiveness. For example, dry detention ponds are typically designed for flood control and have little or no pollutant removal capacity. These facilities have the greatest potential for conversion to an extended detention pond, which is designed to capture and retain stormwater runoff to allow sediments and pollutants to settle out while also providing flood control if necessary. Five dry ponds are located within the watershed; however, none were assessed during the uplands assessment, and it is unknown if there is potential for conversion to a wetland or extended detention facility at these locations.

5.2.1.2 *Storm Drain Inlet and Outfall Retrofits*

Baltimore County's curb and gutter system consists of numerous inlets, pipes, and outfalls. While the curb and gutter system removes stormwater quickly from roadways, it often delivers increased runoff volumes and untreated pollutants to receiving water bodies. One way to address these potential water quality issues is to install proprietary BMPs at selected storm drain inlets. Various structural BMPs are commercially available and include catch basin inserts, water quality inlets, oil/grit separators, filtering devices, and hydrodynamic devices. Proprietary BMPs are designed to address specific pollutants such as floatables and solid waste, nutrients, metals, sediment, and oil/grease. Most are helpful for removing a portion of pollutants for pretreatment when used in conjunction with another BMP type such as an infiltration trench or a grassed swale for filtering pollutants upstream of an inlet.

While proprietary devices can be costly, they are water improvement alternatives for areas where there is inadequate space for other stormwater management options. Inlets selected for proprietary devices can be prioritized based on the county's outfall screening program.

Where space exists between an outfall and the stream channel, other BMPs can be considered such as floodplain wetlands and energy dissipation devices. Floodplain wetlands can provide treatment of storm flows prior to entering the stream channel. Energy dissipation devices can reduce stream power and thus erosive forces of storm flows prior to entering the stream channel.

5.2.1.3 *Public Parking Lot Retrofits*

The potential for installing new stormwater retrofits for treating runoff from existing developed areas is often limited by space availability. However, BMPs that require less space for treating runoff from portions of impervious surfaces can be an alternative to larger storage facilities such as wetlands and extended detention ponds. In areas where insufficient space is available for basin-scale retrofits, other infiltration/filtration practices such as bioretention can be incorporated into the parking lot layout. Bioretention involves open space combined with vegetated areas where stormwater is temporarily stored and passed through vegetation and a filter bed of sand, organic matter, soil, or other suitable media. Filtered stormwater is collected and returned to the storm drain system or allowed to partially exfiltrate from the system into the soil. A few public and private facilities were identified as having sufficient open space for bioretention areas to treat runoff from parking lots. Another retrofit option for treating runoff from large impervious surfaces with limited open space is underground stormwater retention/infiltration systems. Underground stormwater retrofits help address sediment and nutrient inputs to the stream system as well as standing water.

5.2.2 Stream Corridor Restoration

Stream corridor restoration practices are used to enhance the appearance, stability, and aquatic function of stream corridors. These types of practices can range from simple stream clean-ups and localized bank stabilization to comprehensive repairs such as channel re-design and re-alignment. Stream restoration practices are often combined with stormwater retrofits and riparian management practices to meet subwatershed restoration objectives. Primary recommended practices for Liberty Reservoir stream corridors include buffer restoration, stream stabilization, and stream clean-ups.

5.2.2.1 Forest and Buffer Improvement

Forest and wetlands are the best land use for the protection of water quality. The Liberty Reservoir watershed is covered with over 42% forest and may provide opportunities for planting. Forested buffers are linear wooded areas along rivers, streams, and shorelines, which help stabilize banks, prevent erosion, filter pollutants such as sediment and nutrients, provide wildlife habitat, and may provide opportunities for expanding and enhancing forest coverage. Many areas within the Liberty Reservoir stream system have inadequate buffers as a result of human development activities and agricultural clearing. A significant amount of the watershed has been altered and as a result, the original forested stream buffer has been replaced by cropland, pasture, mowed lawn areas, and impervious cover.

The main restoration strategy proposed for the Liberty Reservoir watershed is to conserve and enhance forests and impacted stream buffers. This can be accomplished by a variety of methods including:

- Planting on residential and open space properties with native vegetation – Institutions and residential communities should reduce the amount of mowed grass and plant additional native trees.

- Land Preservation – Forest protection is one reason for pursuing a property as part of the county’s land preservation programs. Benefits to water quality are a part of the evaluation criteria in determining the most important parcels for protection.

- Targeted reforestation and education – Agencies and other watershed partners should seek to work cooperatively with landowners to help them plant buffers where possible. Increase landowner awareness (residents, businesses, and institutions) regarding the benefits of stream buffers that are forested or planted with native vegetation In addition to providing water quality benefits, natural buffers help to protect property from erosion. There is a need for attention in this area, as it was observed that many landowners mow their lawns directly to the stream edge.

Trash dumping and yard waste in neighborhoods, along roadways, and in commercial areas could be addressed as well.

- Invasive species control – Invasive and non-native plant species such as multiflora rose were identified in various locations within the watershed. Invasive species concerns can be addressed through public education, training of county grounds maintenance staff, and developing a volunteer group dedicated to controlling invasive species in the watershed.

5.2.2.2 Stream Stabilization

Natural channel design techniques are utilized to stabilize eroded, degraded stream banks and to protect infrastructure such as private property, buildings, and utilities. Stabilizing the stream channel improves water quality by preventing eroded soils, and the pollutants contained in them, from entering the stream. In addition, protecting infrastructure such as water and storm drain pipes reduces and/or eliminates water quality impacts associated with leaking pipes. Where conditions allow, reconnecting the stream channel to its floodplain provides additional water quality benefits. When considering stream repair, it is important to take into account what is occurring upstream in the watershed. The hydrology and stormwater management practices upstream of a restoration site will dictate the quantity and speed runoff will reach a site. In addition, the sediment supply of the upstream channel is also an important consideration during the design of stream restoration repairs.

5.2.2.3 Wetland Creation

Wetlands are highly valuable lands in terms of their abilities to both improve water quality and as important habitat for many species. Wetlands are defined as areas that are inundated or saturated by surface or groundwater at a frequency sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands are often called swamps, marshes, or bogs. This strategy entails the creation or enhancement of existing wetlands that have been lost or impaired in the past. The County often undertakes wetland restoration on public lands where wetlands have been destroyed or impaired as well as partnering with businesses and institutions where wetland restoration is a viable option.

5.2.2.4 Floodplain Reconnection

Floodplains provide not only flood control, but have stormwater management and water quality benefits. Flooding is a natural process in stream systems and a functioning floodplain enables runoff to be slowed, stored, and gradually released along a vegetated surface. This promotes shallow groundwater recharge, increases pollutant reduction, and reduces the velocity and volume of water to the downstream channel. With a reduction in storm flow velocities, floodplains also aid in erosion control. This strategy involves reconnecting floodplains in areas where development has resulted in disconnection. The County aims to restore natural stream and floodplain function on an individual project basis focusing on urban stream problems.

5.2.3 Pervious Area Restoration

Pervious areas offer a good opportunity for restoration in subwatersheds since they can be used to restore natural infiltration properties, enhance stream buffers, and provide wildlife habitat. These areas also present an opportunity for reforestation in the watershed, which is a high priority in terms of improving infiltration and recharge functions. Other techniques can also be used to improve natural functions including soil aeration, amendments, and establishing native plants and meadows. Sites prioritized for pervious area restoration should require minimal preparation for reforestation or regeneration with little evidence of soil compaction, invasive plant species, and trash/dumping.

5.3 Municipal Management Programs

Municipal management programs are longer-term or continuous actions that Baltimore County can take to improve water quality in the Liberty Reservoir watershed.

5.3.1 Best Management Practices for Developed Land

Development throughout the watershed is largely responsible for increased pollutant loads and storm flow rates. Best management practices can be adopted in order to reduce the impacts of development and restore the quality of receiving waters.

5.3.1.1 Trash Management/Education

Dumping of bulk materials was noted during the upland and stream assessments. Existing trash initiatives include Adopt-A-Road, inmate roadside cleanups, and Clean Green 15. Watershed associations organize many stream cleanups throughout the county. Project Clean Stream, the Alliance for the Chesapeake Bay's annual region-wide stream clean up event engaged 7,500 volunteers at over 250 sites at its 2014 event. Implementing more municipal practices and programs related to trash management/education in the Liberty Reservoir watershed would improve water quality and aesthetics of the watershed.

A county-wide Trash and Litter Reduction Strategy is being developed by EPS in conjunction with other county departments to address litter. It will provide the foundation for future Trash Total Maximum Daily Load (TMDL) Implementation Plans.

5.3.1.2 Tree Planting

Several opportunities for reforestation and buffer improvement were identified during the field assessments, including for planting of shade trees in various neighborhood open spaces, as well as open pervious areas, stream buffers, and institutions throughout the watershed. For smaller planting projects, citizens can purchase trees at low cost through the MD Department of Natural Resources (DNR's) Tree-mendous Maryland program for planting on community open spaces and public lands, or through the county's Big Trees program for planting on private residential yards. For planting on larger properties, especially for reforestation greater than one acre, citizens can contact EPS about opportunities for reforestation "turf-to-trees" projects funded through the stormwater remediation fees. These projects cover site preparation, planting, deer shelters, and monitoring and maintenance for three years.

5.3.1.3 Inlet Cleaning

Over time, solids in stormwater runoff collect in storm drains and inlets. As solids accumulate in an inlet, they are susceptible to downstream transport during larger storm events, contributing to pollution in the Liberty Reservoir watershed. A study conducted by the University of Maryland, Baltimore County (UMBC) and the Center for Watershed Protection as part of the United States Environmental Protection Agency (USEPA) Chesapeake Bay Program (CBP) concluded that annual or semi-annual cleaning of storm drain inlets can significantly increase solids removal rates (18-35%) while also contributing to nitrogen and phosphorus removal (Law, 2008). The Department of Public Works cleans inlet grates on a routine basis (EPS, 2013). Inlet boxes and pipes are cleaned as needed. Inlet cleaning at regular intervals can reduce pollutant loads in the watershed, reduce flooding and help locate illicit discharges in the storm sewer system.

5.3.1.4 Erosion and Sediment Control

Construction activities near storm drain systems were observed during the field assessments. Erosion and sediment controls are vital to prevent soil and other pollutants from entering the storm drain system or nearby streams. Follow-up inspections and improvements to substandard erosion and sediment control practices at construction sites are implemented and enforced by the Baltimore County Department of Permits, Approvals, and Inspections to prevent sediment and other pollutant inputs from entering into the storm drain system and stream network.

5.3.1.5 Dry Weather Discharge Prevention

Baltimore County’s illicit connection detection and elimination program targets dry weather flows into the storm drain system, which contain significant pollutant loads. Examples include illicit discharges, sewage overflows, or industrial and transportation spills. Dry weather discharges can be continuous, intermittent, or transitory. Resulting water quality problems can be extreme depending on the volume and type of discharge. For example, sewage discharges include bacteria and can directly affect public health while other discharges such as oil, chlorine, pesticides, and trace metals can be toxic to aquatic life. Dry weather discharge prevention focuses on four major sources that can occur in a subwatershed as described briefly below:

- Illicit Sewage Discharge: When septic systems fail or when sewer pipes are mistakenly or illegally connected to the storm drain pipe network, sewage can get into streams. Sometimes sewage is directly discharged to a stream or ditch without treatment or illegally dumped into the storm drain system from boats or RVs.
- Commercial and Industrial Illicit Discharge: Some businesses mistakenly or illegally dispose of liquid wastes that can adversely impact water quality into the storm drain system. Examples include hotspots where materials such as oil, paint, and solvents are improperly disposed, where

businesses' drains are directly connected to the storm drain system, or where untreated wash water or process water is dumped into the storm drain system.

- Industrial and Transport Spills: Pollutants can enter the storm drain system as a result of ruptured tanks, pipeline breaks, accidents/spills, or illegal dumping. These events are more likely to occur in urban subwatersheds and may result in potentially hazardous materials reaching streams through the storm drain system.
- Failing Sewage Lines: Sewer lines often follow the stream corridor. If they leak, overflow, or break, sewage will be discharged directly into the stream. The frequency of failure depends on the age, condition, and capacity of the existing sanitary sewer system. This is not a major concern for the Liberty Reservoir watershed as the majority of the watershed (93%) falls outside the Urban Rural Demarcation Line (URDL) and does not have access to sanitary sewer lines.

5.3.2 Land Preservation

Land preservation compliments the implementation of BMPs by insuring that specific non-urban land uses remain intact over time on specific parcels of land. Land preservation includes areas such as parks and watershed protection zones where non-extractive uses are prevalent, as well as areas that are intensively managed for agriculture.

Land preservation parcels may be large (i.e. parks) or small (i.e. single farm). Land preservation reflects societal priorities and decisions to limit urban and residential development, and provides broad benefits. However, land preservation alone may or may not attain certain environmental goals, such as improved water quality.

"Protected land" includes any land with some form of long-term limitation on conversion to urban/developed land use. This protection may be in various forms: public ownership for natural resource or low impact recreational intent (i.e. park), private ownership where a third party acquired the development rights or otherwise required the right to limit use through the purchase of an easement (i.e. conservation easement). The extent of "protection" varies greatly from one situation to the next. Therefore, for some protected land, it may be necessary to explore the details of land protection parcel-by-parcel through the local land records office to determine the true extent of protection.

For purposes of watershed management, an understanding of existing protected lands can provide a starting point in prioritizing potential protection and restoration activities. In some cases, protected lands may provide opportunities for restoration projects because owners of these lands may value natural resource protection or enhancement goals. A summary of current conservation easements is provided in Chapter 2, Section 2.3.10.1.

Maryland and County Rural Legacy Program

Baltimore County participates in the State Rural Legacy Program which was developed in 1997 to protect large, continuous tracts of valuable cultural and natural resource lands through grants made to local applicants. Baltimore County's Rural Legacy Program aims to protect large blocks of forest, wetlands, farms, and other open spaces that are of significant ecological value as habitat for rare, threatened, and endangered species and to preserve the environmental benefits that these areas provide to the Chesapeake Bay.

Maryland Environmental Trust (MET) and Local Land Trusts

Created by the Maryland General Assembly in 1967 to protect Maryland's natural environment, the Maryland Environmental Trust (MET) seeks donated easements on farms and forestlands, wildlife habitats, waterfront acreages, natural areas, historic sites, and other valuable and scenic features. In 1974, a landowner in Baltimore County was one of the first to protect their property through this program. Today, Baltimore County remains a leader in the state, with county landowners preserving over 12,000 acres through donations. Although both MET and local land trusts prefer to accept donations on lands greater than 50 acres, local land trusts are often willing to work with smaller property owners. Donations are accepted throughout the year. Landowners may qualify for a significant tax deduction and/or credit. MET also provides loans to qualified groups for the purchase of land for preservation.

Baltimore County Agricultural Land Preservation Program

The Baltimore County Agricultural Land Preservation Program was developed in 1994 to preserve working family farms. The County has used innovative and collaborative funding mechanisms for land preservation. Eligible farms must be at least 50 acres in size or 20 acres if contiguous to an existing easement and meet certain soil criteria. Currently, approximately 3,300 acres of land are preserved through this program.

Maryland Agricultural Land Preservation Foundation (MALPF) Easements

This program is a joint effort between the state and the county and is the main agricultural land easement program in Baltimore County. The program has been in existence since 1977 and aims to preserve sufficient agricultural land to maintain a viable local base of food and fiber protection for the present and future citizens of Maryland and protect and enhance the environmental quality of wildlife habitat and the Chesapeake Bay. MALPF also preserves forested properties. Development on the easements (both forest and farm) is restricted.

DNR Land Conservation Easements

DNR holds conservation easements over land including the state park service. In the Liberty Reservoir watershed, the DNR maintains the Soldiers Delight Natural Environment Area which is 1,900 acres and preserved under State Wildlands Status for nature appreciation and outdoor adventures.

Local Land Trusts

Local land trusts are another method of land conservation whereby the landowner may donate or sell part of their land to a land trust as a conservation easement. Many of the lands held by local land trusts are co-held with one of the aforementioned programs. In the Liberty Reservoir watershed there is one local land trust operating: the Land Preservation Trust.

5.3.3 Best Management Practices for Agricultural Land

Agricultural land makes up approximately 25% of the Liberty Reservoir watershed. The Maryland Agricultural Water Quality Cost-Share (MACS) Program encourages implementation of agricultural BMPs by providing farmers with grants that cover up to 87.5 percent of the installation cost. Approximately 30 different BMPs are eligible for MACS grants. Funding is also available through various federal programs. Eligibility of the grants requires the practice to address and treat Nonpoint Source (NPS) pollution related to agricultural sources and be located on a farm.

5.3.3.1 Farm Conservation Plans

Farm conservation plans are agronomic, management, and engineered practices that protect and improve soil and water quality. They also aim to prevent the deterioration of natural resources on a farm. Plans include best management practices to manage the farm's resources, control soil erosion, and protect water quality. The Maryland Department of Agriculture refers to these plans as Soil Conservation and Water Quality Plans (SCWQP). These plans are required by the Federal Food Security Act on all highly erodible lands and farmland enrolled in the Maryland Agricultural Land Preservation Foundation Program. A number of the BMPs considered in conservation plans are listed below.

Cover Crops

Implementation of cover crops improves water quality by recycling unused plant nutrients and protecting fields against wind and water erosion. This practice also increases the productivity of farmland and improves the soil for the next season's crops. Maryland nutrient management regulations require farmers to plant cover crops when organic nutrient sources are applied to fields in the fall. Grants are available to offset the costs of seed, labor, and equipment through the Maryland Agricultural Water-Quality Cost-Share (MACS) Program and are funded by the Chesapeake Bay Restoration Fund and Chesapeake Bay 2010 Trust Fund. For 2014, MACS allocated approximately $20 million towards the cover crop program. Guidelines and conditions determine the amount of incentive payments to be paid and applications must be submitted during specified times at soil conservation district offices statewide to be considered.

Conservation Tillage

Conservation tillage entails planting and growing crops with minimal disturbance to the surface soil. One form of conservation tillage is no-till farming where the crop is seeded directly into vegetative cover or crop residue with very little disturbance of the surface soil. Additionally, minimum tillage farming involves some soil disturbance, but uses tillage equipment that leaves much of the vegetation cover or crop residue on the surface. Conservation tillage requires two components: a minimum 30% residue coverage at the time of planting and a non-inversion tillage method. There are no cost-share measures for conservation tillage; however, the State of Maryland offers income tax subtraction modification to offset the costs associated with buying certain types of conservation tillage equipment.

Agricultural Riparian Forest/ Grass Buffers

Riparian forest buffers are wooded areas along streams that help filter nutrients, sediments and other pollutants from upland areas and help remove nutrients from groundwater. Forest buffers also help control flooding and reduce erosion while creating habitat for wildlife. Mature forested buffers can help remove up to 90 percent of nutrients running off the land. Ideally, forested buffers extend 100 feet along each bank but 35 feet at a minimum.

Like forest buffers, riparian grassed buffers are linear strips of maintained grass or other non-woody vegetation between the edge of field and streams. Grass buffers help filter nutrients, sediments, and other pollutants from runoff and remove nutrients from groundwater.

Cost-share grants are available for planting riparian forest and/or grassed buffers through the MACS program and United States Department of Agriculture's (USDA's) Conservation Reserve Enhancement Program (CREP).

Animal Waste Management

Animal waste management programs are designed to ensure the proper handling, storage, and utilization of wastes generated from animal operations. This requires collecting, scraping or washing wastes and contaminated runoff from confinement areas into appropriate facilities. Controlling runoff from these areas is an integral part of the management system.

The Maryland Department of Agriculture (MDA) promotes a manure transport and matching program that helps livestock producers with excess manure comply with their nutrient management plans and transport the excess manure in an environmentally safe manner. There is a cost-share assistance program to help farmers cover the cost of transporting the manure. This helps protect water quality in streams and rivers.

Stream Protection with Fencing

Under Maryland's new nutrient management regulations, as of January 1, 2014, livestock access to streams is to be restricted by a minimum 10 foot setback. Fencing is not required under this regulation, however it may be the only option. Stream protection with fencing limits livestock access to streams and protects the stream buffer which may be planted. Cost-share grants are available for planting riparian forest and/or grassed buffers through the MACS program and USDA's Environmental Quality Incentives Program (EQIP).

Off Stream Watering

Creating alternative watering facilities for livestock through permanent or portable water troughs placed away from stream corridors improves water quality and prevents stream bank erosion. By removing livestock from the stream corridor, vegetative cover along the stream is protected, preventing erosion and pollution from nutrients, sediments, and animal wastes. Cost-share for watering facilities is available through the MACS program.

5.3.3.2 Nutrient Management Plans

As a result of 1998 legislation and the Water Quality Improvement Act, all Maryland farmers grossing $2,500 or more annually or raising 8,000 pounds or more of live animal weight are required to produce and operate using a nutrient management plan that addresses nitrogen and phosphorus inputs (MDA, 2014). These plans aim to specify the amount of nutrient sources (fertilizer, manure, etc.) that can safely be applied to farmland in order to achieve yields and prevent excess nutrients from entering waterways. The MDA currently monitors the implementation of these plans and issues penalties and fines for violations. Currently, there are no cost-sharing opportunities from MDA for nutrient management plans.

5.3.3.3 Federal Financial Assistance

A number of funding opportunities are available through the Natural Resources Conservation Service (NRCS) to manage natural resources in a sustainable manner (NRCS, 2014). Under the 2014 Farm bill, there are currently three different programs for financial assistance to help agricultural producers make and maintain conservation improvements on their land. The former Wildlife Habitat Incentive Program (WHIP) is now part of the Environmental Quality Incentives Program (EQIP) that provides financial and technical assistance to agricultural producers to implement conservation practices and deliver environmental benefits. There is also the Agricultural Management Assistance (AMA) program that helps agricultural producers use conservation to manage risk and solve natural resource issues. This program is available in 16 states including Maryland. Finally, there is the Conservation Stewardship Program (CSP) that helps agricultural producers maintain and improve their existing conservation systems. CSP payments are earned based on conservation performance – the higher the performance, the higher the payment. All of these programs must be applied for through the USDA.

5.4 Volunteer Restoration Programs

Volunteer restoration programs include activities or projects conducted by volunteers and volunteer organizations such as a watershed improvement group.

5.4.1 Stream Cleanups

Stream clean-ups are a simple practice used to enhance the appearance of the stream corridor by removing unsightly trash, litter, and debris. These are usually performed by volunteers and are one of the most effective methods for generating community awareness and involvement in watershed activities. Public outreach tools should be used to encourage and inform residents about organizing stream clean-ups.

5.4.2 Tree Planting

As previously mentioned, a number of open space planting opportunities are present in the Liberty Reservoir watershed, offering an opportunity to apply for municipal tree planting programs including Maryland's State Highway Association (SHA's) "Partnership Program" and DNR's "Tree-mendous Maryland" program to help reforest public lands within the watershed. These types of programs also provide an opportunity to involve volunteers from various neighborhoods, businesses, and schools to help plant trees throughout the watershed while educating the community about the importance of trees for air and water quality benefits.

5.4.3 Storm Drain Marking

Most of the developed areas in the Liberty Reservoir watershed consist of curb and gutter systems including storm drain inlets that convey stormwater runoff quickly and directly to the stream system. Some inlets have grates with storm drain marking but many inlets do not have any indicators that they drain to the local streams. Since there is little or no infiltration of stormwater in a curb and gutter system, there is more potential for pollutants to be carried to the stream system. Storm drain marking is a way to educate residents that anything building up along the curbs and gutters such as trash and lawn clippings will be washed away after a storm event and end up in the streams.

5.5 Business and Institutional Initiatives

Business and institutional initiatives include activities that are available for commercial businesses and institutions to undertake in order to improve water quality in the area.

5.5.1 Impervious Cover Removal

Impervious surfaces including roads, parking lots, roofs, and other paved surfaces prevent precipitation from naturally seeping into the ground. Stormwater runoff from impervious surfaces is often concentrated, accelerated, and discharged directly to the storm drain system or nearest stream. This can result in erosion, flooding, habitat destruction, and increased pollutant loads to receiving water bodies. Subwatersheds with high amounts of impervious cover are more likely to have degraded stream systems and be significant contributors to water quality problems in the watershed than those that are less developed.

Unused or unmaintained impervious surfaces with the potential for removal were identified at several institutions. At sites where parking lots may be larger than necessary, portions of the impervious cover could be removed and converted to bioretention areas for treating stormwater runoff from the remaining impervious surfaces. Some institutions may also have parking areas that are not frequently used (e.g., cemeteries) and could be suitable for conversion to permeable pavement which allows some infiltration of stormwater runoff while providing support for less frequent traffic/vehicle use. Several neighborhoods have unpaved driveways, which allow some infiltration of stormwater runoff. However, completely paved driveways were more common in the neighborhoods assessed during this study. Education and outreach tools could be used to inform residents of the water quality impacts associated with large impervious driveways or patios and options available for conversion to or incorporation of more permeable surfaces such as grass strips, gravel, or permeable pavers.

5.5.2 Potential Redevelopment of Urban Areas

Natural areas that are developed into impervious urban landscapes result in an increase in runoff and pollutant loading. Redeveloping these urban areas back into a more natural setting can provide nutrient load reductions. In the Water Resources Element of its Master Plan 2020, Baltimore County has analyzed redevelopment scenarios and identified potential land for redevelopment in each of its watersheds.

Urban watersheds developed prior to modern stormwater regulations have fewer or no stormwater management facilities to capture and treat stormwater runoff. As businesses and property owners choose to redevelop properties that already have high amounts of impervious cover, they must meet redevelopment regulations in Baltimore County requiring a 50% reduction in impervious surface or inclusion of equivalent stormwater quality management facilities. Limited opportunity for redevelopment exists in Liberty Reservoir.

5.5.3 Pervious Area Restoration

Most of the institutions assessed in Liberty Reservoir had opportunities for reforestation which would also require less ground maintenance than mowed lawn and improve energy efficiency. Parcels meeting these criteria are good candidates for follow-up investigations and landowner contact.

5.5.4 Stormwater Retrofits

The following represent stormwater retrofits that can be undertaken by private entities to positively affect water quality.

5.5.4.1 Parking Lot

A few institutions were identified as having sufficient open space for bioretention areas to treat runoff from impervious areas. Another retrofit option for treating runoff from large impervious surfaces with limited open space is underground stormwater retention/infiltration systems. Stormwater retrofits would help address sediment and nutrient inputs to the stream system.

5.5.4.2 Downspout Disconnection

Downspouts directly connected to the storm drain system or draining to impervious surfaces such as parking lots, sidewalks, or the curb and gutter system increase the volume and flow rate of pollutant-laden runoff reaching streams. Disconnected downspouts allow rooftop runoff to infiltrate into the ground and enter streams through the groundwater system in a slower more natural fashion. This decreases flow to local streams during storm events and helps prevent erosion and reduces pollutant loads to streams. Disconnecting downspouts in commercial corridors is an inexpensive way to improve water quality in the Liberty Reservoir watershed.

5.5.5 Open Space Planting

Several opportunities for reforestation and buffer improvement were identified during the field assessments including open space shade tree plantings in various open pervious areas and institutions throughout the watershed. This presents an opportunity to apply for municipal tree planting programs including SHA’s Partnership Program and DNR’s Tree-Mendous Maryland program to help reforest areas of the watershed.

Tree-Mendous Maryland coordinates the free delivery of trees to citizens and community groups, and provides an inexpensive way to obtain trees and shrubs for planting on public lands and within community open spaces. These types of programs also provide an opportunity to involve volunteers from various neighborhoods, businesses and schools to help plant trees throughout the watershed while also educating the community about the importance of trees for air and water quality benefits.

5.5.6 Pollution Source Control

Hotspots are commercial, industrial, municipal, or transport-related operations in the watershed that tend to generate higher concentrations of stormwater pollutants and/or have a higher risk of spills, leaks, or illicit discharges. Pollution prevention practices can significantly reduce hotspot pollution problems. Local government agencies must adopt pollution prevention practices for their operations and lead by example. This should be followed by inspection and incentive-based educational efforts for privately operated sites with enforcement measures as a backstop. The ability to conduct such inspections and enforcement actions should be clearly articulated in local codes and ordinances and through education programs. As previously noted, some industrial/commercial sites are required to have National Pollutant Discharge Elimination System (NPDES) permits for stormwater and/or wastewater discharges. While the County assists with the identification of these sites, Maryland Department of the Environment (MDE) is responsible for regulating industrial/commercial sites that are required to have NPDES permits. Another potential program is to host workshops for local businesses that detail the permit requirements and how to prepare pollution prevention plans.

5.6 Citizen Awareness Activities

Citizen awareness activities are actions that any resident or citizen in the Liberty Reservoir watershed can take that would provide a benefit to water quality.

5.6.1 Pollution Prevention/Source Control Education

Residents often engage in behaviors that can adversely impact water quality. Some of these behaviors observed during the assessment of neighborhoods in the watershed include over-fertilizing lawns, excessive use of pesticides, improper storage of potentially hazardous materials (e.g., household cleaners, paints, automotive fluid, etc.), and dumping into storm drains (e.g., wash water). Pollution prevention/source control education efforts should also target waste management activities in the watershed to address dumpsters located near storm drain inlets or streams without diversion methods, poor dumpster conditions (leaking, overflowing, and uncovered), and the occurrence of trash dumping in the watershed. Positive behaviors were also observed such as tree planting, disconnected downspouts, and picking up pet waste which can help improve water quality. A pollution prevention program can be designed to discourage negative behaviors and/or encourage positive behaviors. Either way, the goal is to deliver a specific message through targeted education to promote behavior changes. Local watershed organizations can help influence these changes using pollution prevention education and outreach to teach citizens how to properly care for the watershed.

5.6.2 Trash and Recycling

Educating the public about the trash issues and impacts to water quality in the watershed through a trash campaign is one way to address trash and dumping problems. Baltimore County has implemented a Clean Green County initiative to encourage voluntary litter pickups. The County's Single Stream Recycling program launched in 2010 allows residents to set out all their recyclables for once-a-week collection. A targeted campaign could be launched in the Liberty Reservoir watershed with a slogan and messages tailored to the residents and issues in the study area. By adopting a slogan and campaign for the watershed, residents will be aware of the issues and encouraged to take responsibility for the health of

Liberty Reservoir in their communities. Public education and awareness can also be accomplished through community clean-ups in neighborhoods or schools with observed trash management issues.

5.6.3 Environmental Awareness and Education

Community-based facilities present good opportunities for educating the public about water quality issues and improvement methods for the watershed. This can be accomplished by implementing water quality BMPs such as rain gardens and bioretention facilities at these sites. In addition to environmental education, these BMPs have water quality and aesthetic benefits for property users. There is also potential for involving the community through BMP installation and maintenance. Environmental education can also be accomplished through water quality sampling and monitoring of stormwater management measures such as wetlands and extended detention ponds at schools, for example. Buffer and tree planting activities also present an opportunity for combining community involvement and environmental education.

5.6.4 Bayscaping

A "Bayscape" is a landscape using native plants to provide habitat for local and migratory animals, improve water quality, and reduce the need for chemical pesticides and herbicides. Bayscaping plants, such as trees, shrubs and perennials, are able to make better use of rain water than typical lawn grasses, and so require less watering once established. They are also better at trapping and removing nitrogen and pollutants from rain water so that it is not released into nearby water bodies. A Bayscape is also valuable for the gardener or landowner because it offers greater visual interest than lawn, reduces the time and expense of mowing, watering, fertilizing and treating lawn and garden areas, and can address areas with problems such as erosion, poor soils, steep slopes or poor drainage.

5.6.5 Lot Canopy Improvement

Implementing programs that promote tree planting in residential yards and commercial open space can increase overall tree canopy, slowing runoff rates and allowing greater infiltration of stormwater into the ground. Tree roots also stabilize soils and provide wildlife habitat. Many of the neighborhoods assessed in the Liberty Reservoir watershed had large lots with space available for tree planting.

Currently, Baltimore County hosts a Big Trees Sale in the fall and spring of each year featuring a selection of native trees intended to be planted on private residential properties. The sale provides species such as oaks and maples that grow taller and cast shade over a wider area than smaller trees. The trees help with stormwater infiltration, erosion control, and pollutant reduction. The State of Maryland also has a program called "Marylanders Plant Trees" that encourages citizens to plant and register trees. The program provides $25 off coupons for trees on a recommended tree list valued at or above $50 at participating nurseries and garden centers.

5.6.6 Downspout Disconnection

Approximately 9% of the neighborhoods assessed in the Liberty Reservoir watershed were recommended for downspout disconnection. This is because many of the downspouts were directly connected to the storm drain system or indirectly connected, draining to impervious surfaces such as driveways, sidewalks, or the curb and gutter system. Disconnected downspouts allow rooftop runoff to infiltrate into the ground and enter streams through the groundwater system in a slower more natural fashion. By using pervious ground to intercept and infiltrate runoff prior to its entering a conveyance system (i.e. gutter, inlet, and pipe), neighborhoods can be altered to mimic the predevelopment hydrology of the area to a greater extent. This decreases flow to local streams during storm events and helps prevent erosion and reduce pollutant loads to streams. Many of the typical lots in the Liberty Reservoir watershed have sufficient room for rain gardens and can be implemented with homeowner outreach. Alternatively, redirecting downspouts to pervious areas such as yards or lawns or to rain barrels were also viable options for neighborhoods recommended for downspout disconnection.

Rain gardens are the most desirable option in terms of water quality because they consist of native plants that capture and treat runoff. The majority of homes in the Liberty Reservoir watershed can accommodate these gardens as there were several hundred square feet of open pervious area available down gradient from the downspout in most cases. Rain gardens may also be an option for disconnecting downspouts at institutional sites with sufficient space available. Redirecting downspouts to pervious areas or rain barrels is also an option for institutional sites as well as individual homeowners.

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APPENDIX A:

STREAM CORRIDOR ASSESSMENT DATA

Stream Corridor Assessments

Stream corridors were assessed by two person teams in the Cliffs Branch, Keyser Run, and Norris Run subwatersheds. Along the 22.8 miles of stream assessed, locations of observed environmental problems were recorded as well as potential restoration opportunities. The assessment protocol is explained in detail in Section 3.6.1 of the Liberty Reservoir Watershed Characterization Report. This appendix includes 12 maps that detail the locations and site identifiers for each environmental problem site documented during the SCAs.

Figure 1 shows the locations with the watershed of each of the 12 maps. Figure 2 through Figure 37 display the locations of erosion sites (ES), inadequate buffers (IB), channel alteration sites (CA), exposed pipes (EP), fish migration barrier (FB), pipe outfalls (PO), trash dumping (TD), and unusual conditions or comments (UC) in more detail with their corresponding site identifiers. Erosion sites and inadequate buffers are shown separately on maps, while the additional feature sites are shown together.

All of the data collected during the SCAs are compiled at the end of the document. Each site is listed in further detail and corresponds to the site identifiers labeled on the feature maps.

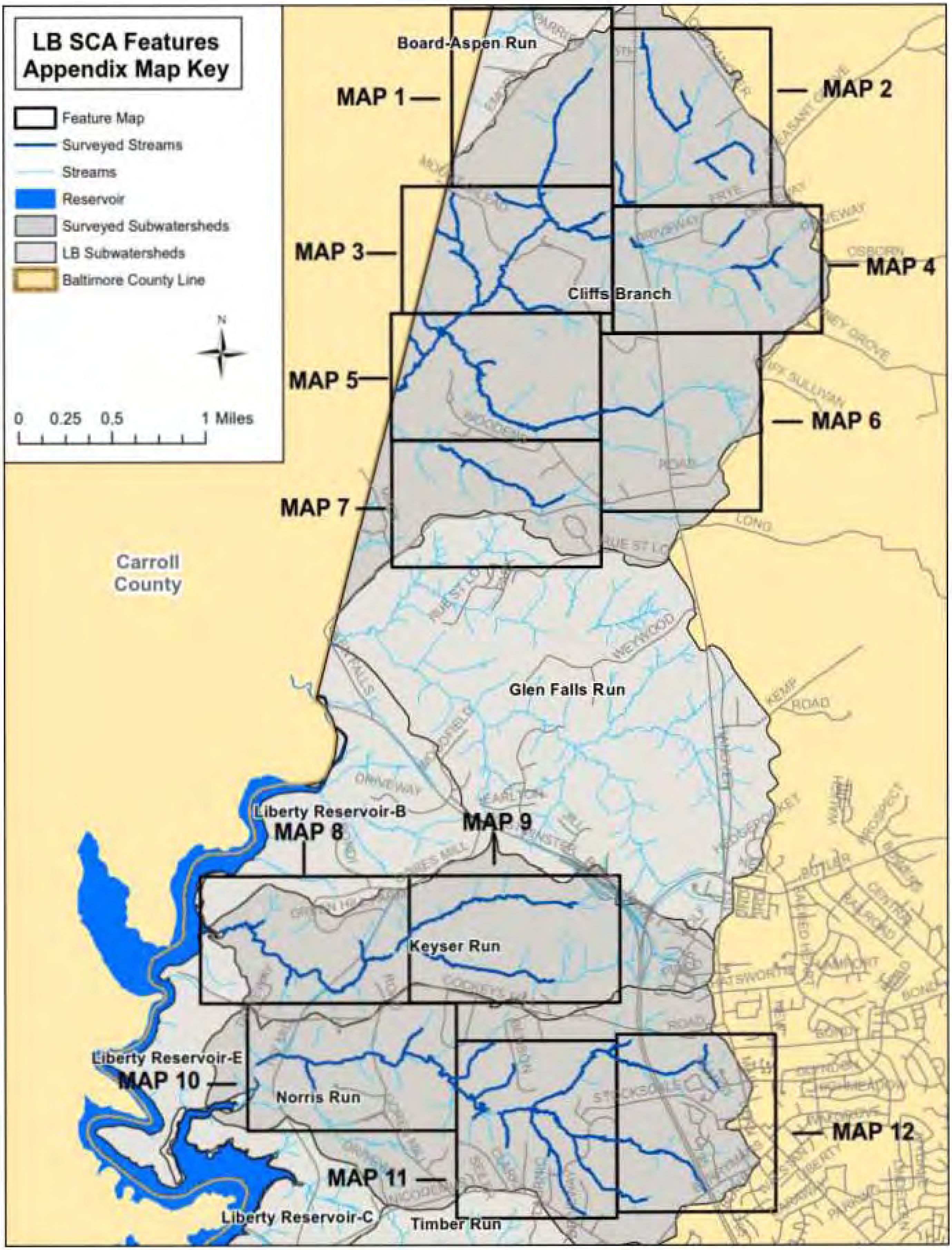

Figure 1: Location of SCA Problem Sites in Liberty Reservoir: Key Map

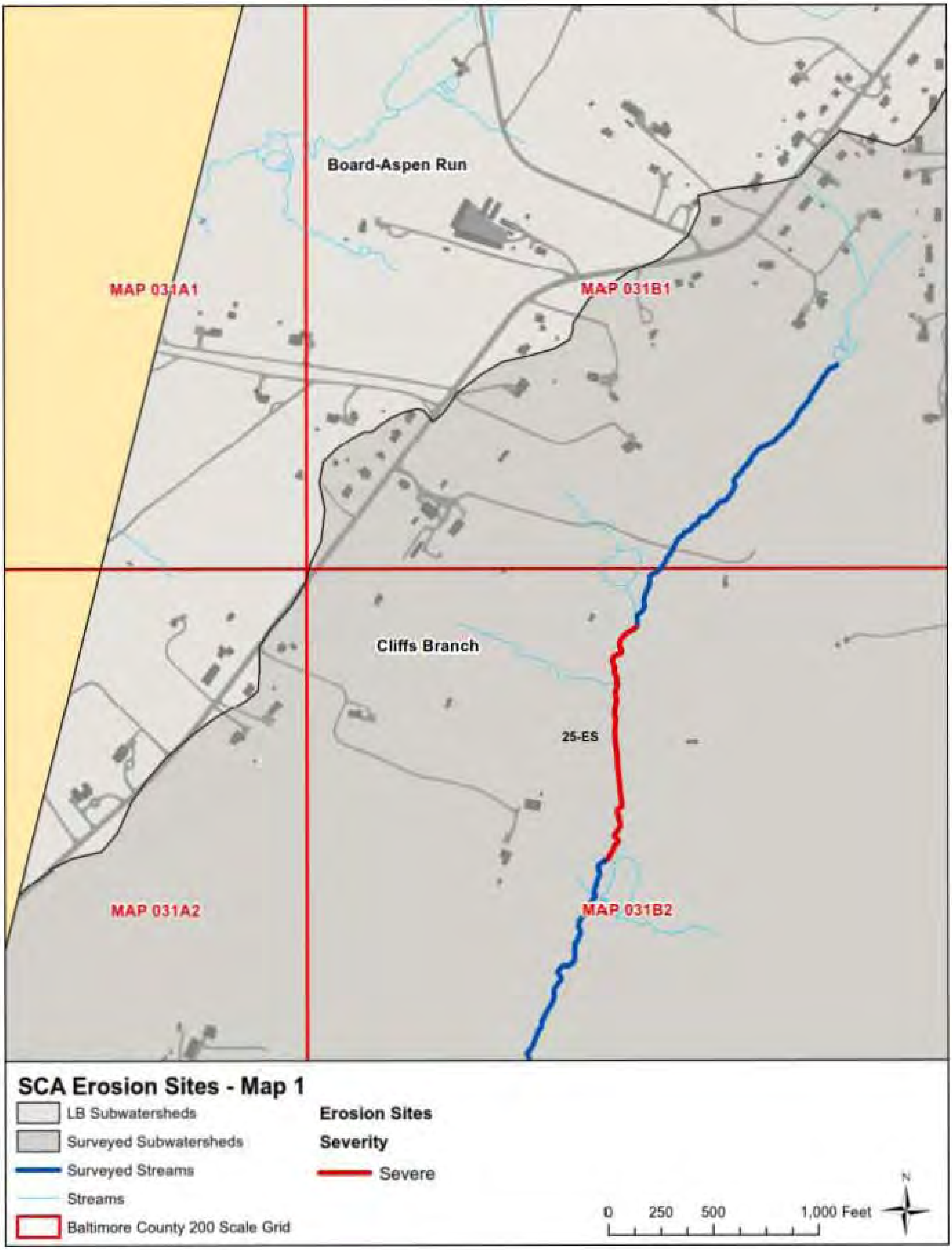

Figure 2: Location of Erosion Sites in Liberty Reservoir: Map 1

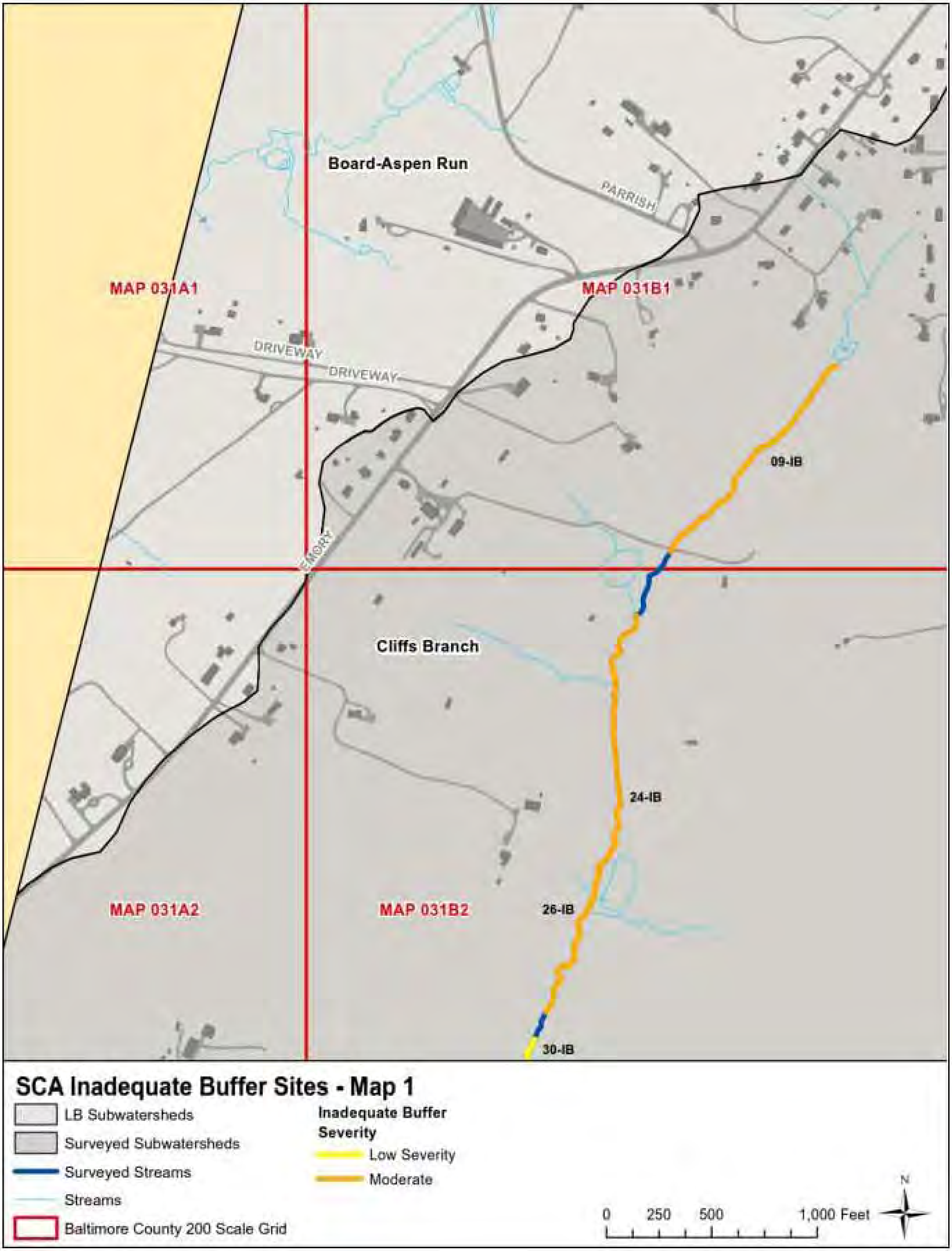

Figure 3: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 1

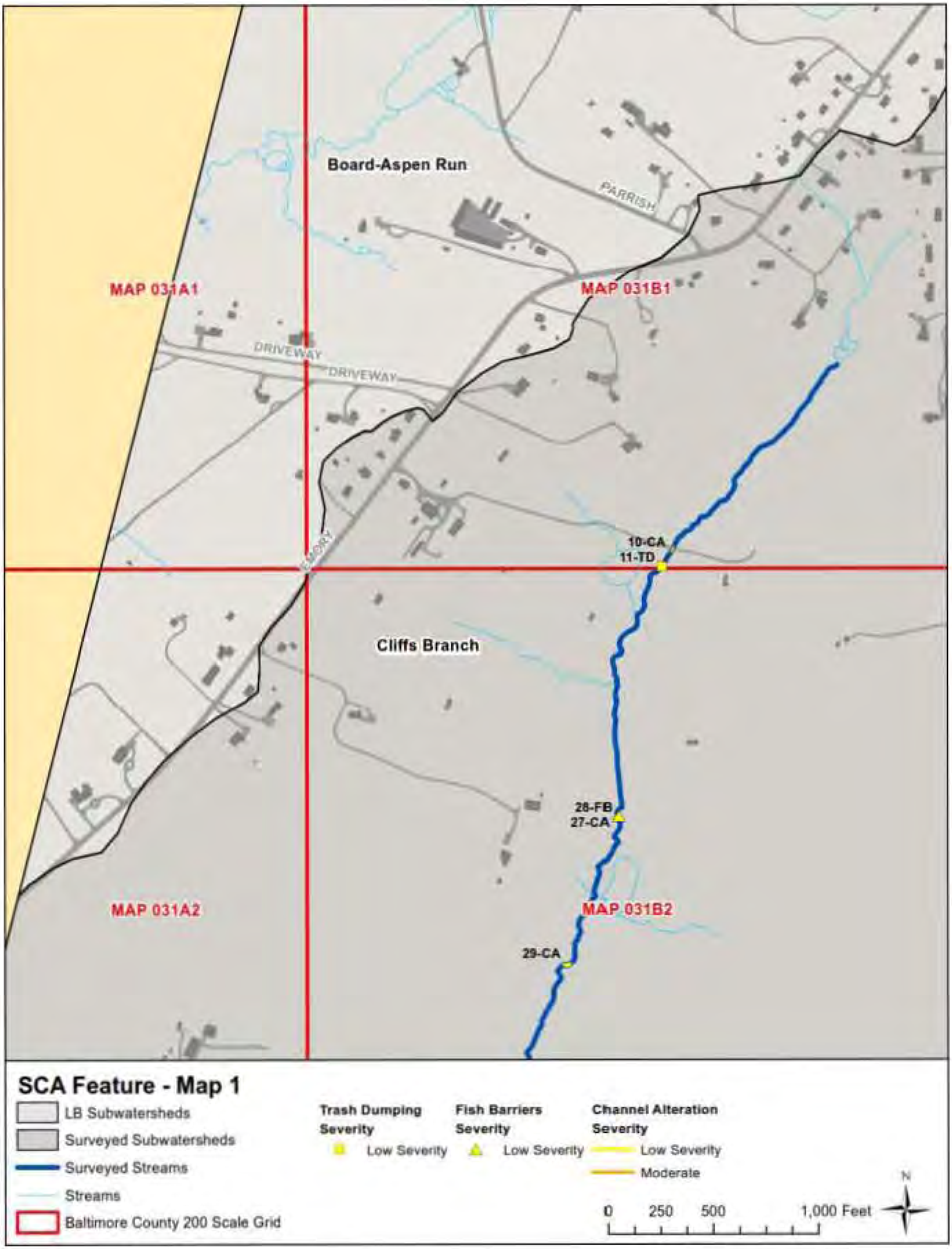

Figure 4: Location of Other SCA Problem Sites in Liberty Reservoir: Map 1

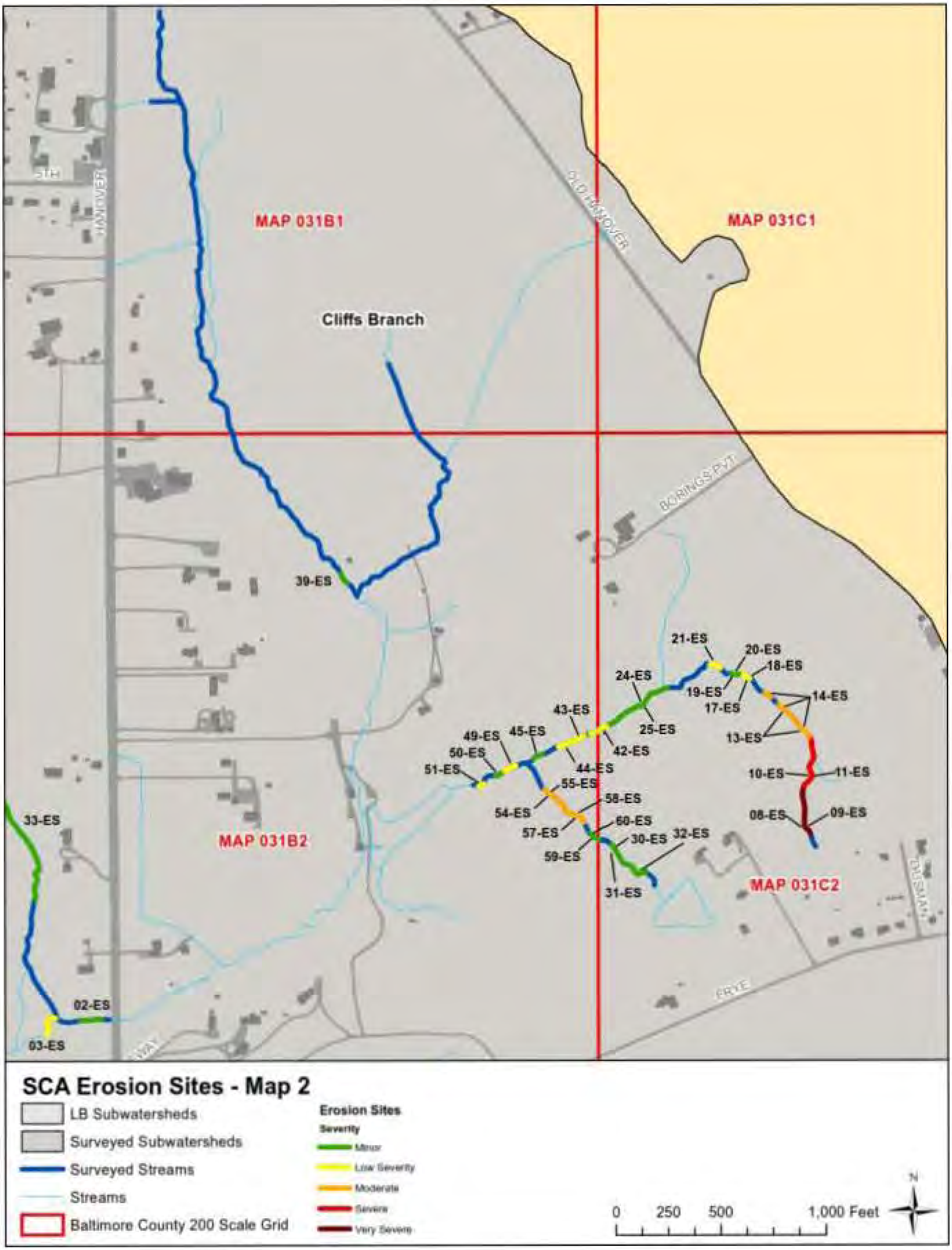

Figure 5: Location of Erosion Sites in Liberty Reservoir: Map 2

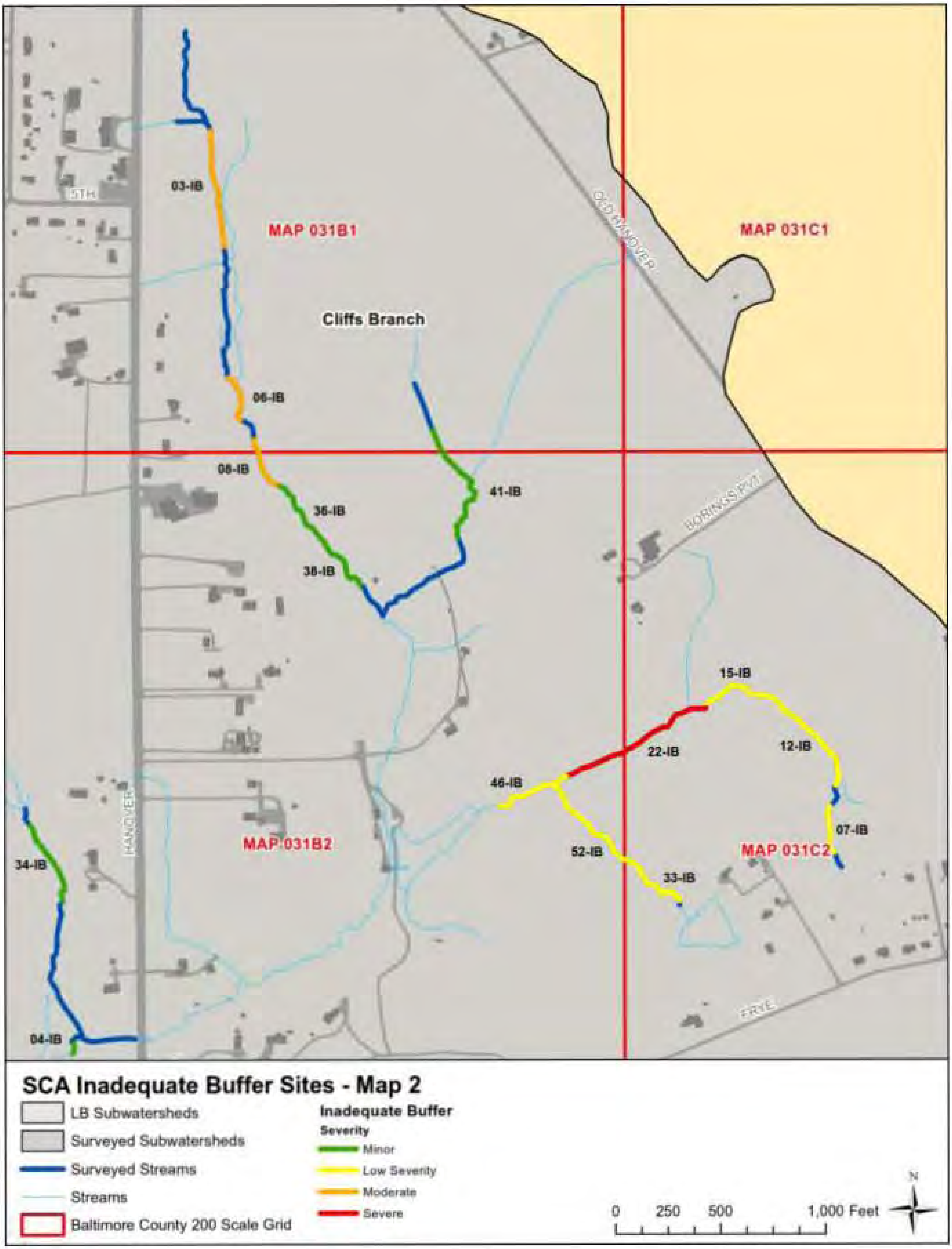

Figure 6: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 2

Figure 7: Location of Other SCA Problem Sites in Liberty Reservoir: Map 2

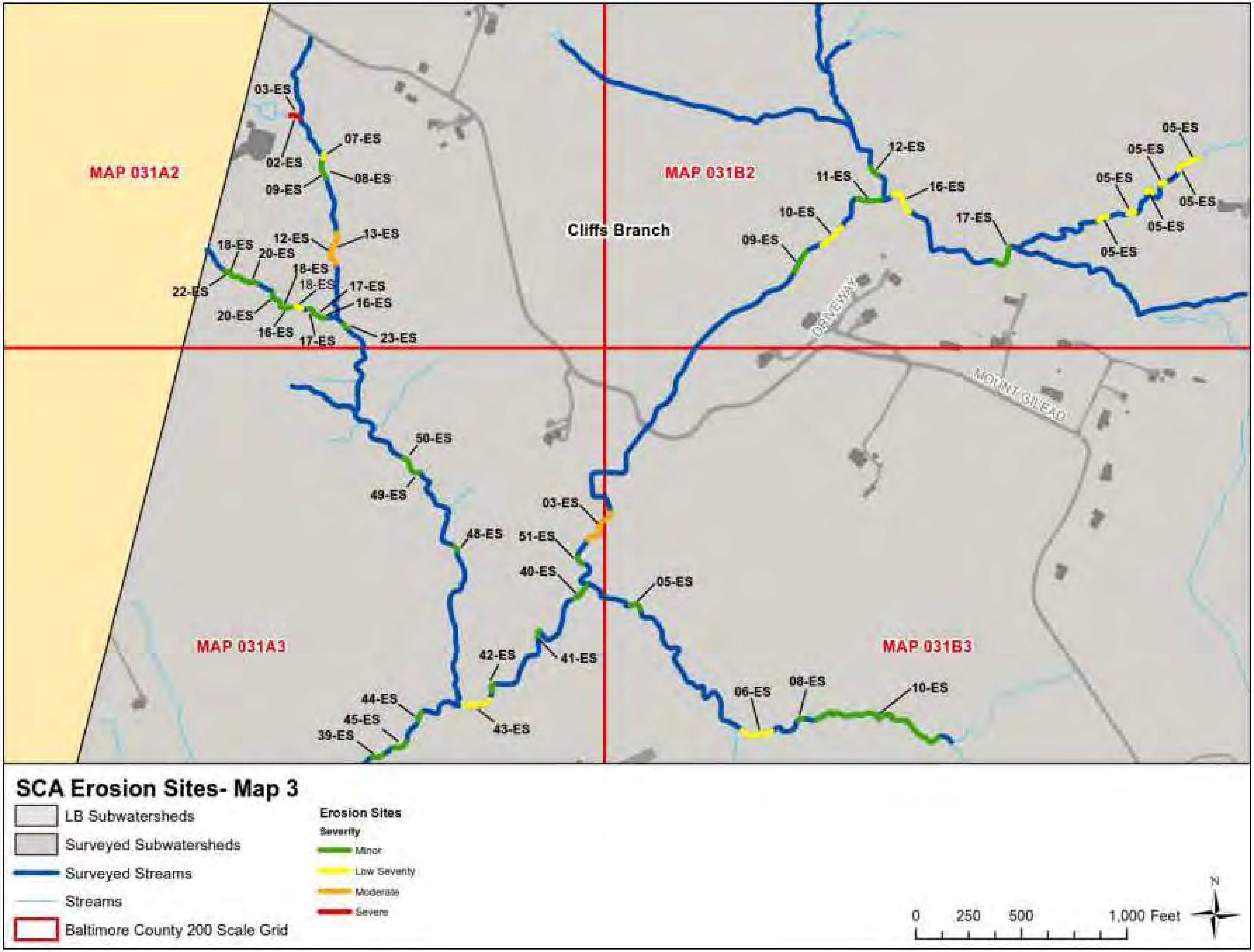

Figure 8: Location of Erosion Sites in Liberty Reservoir: Map 3

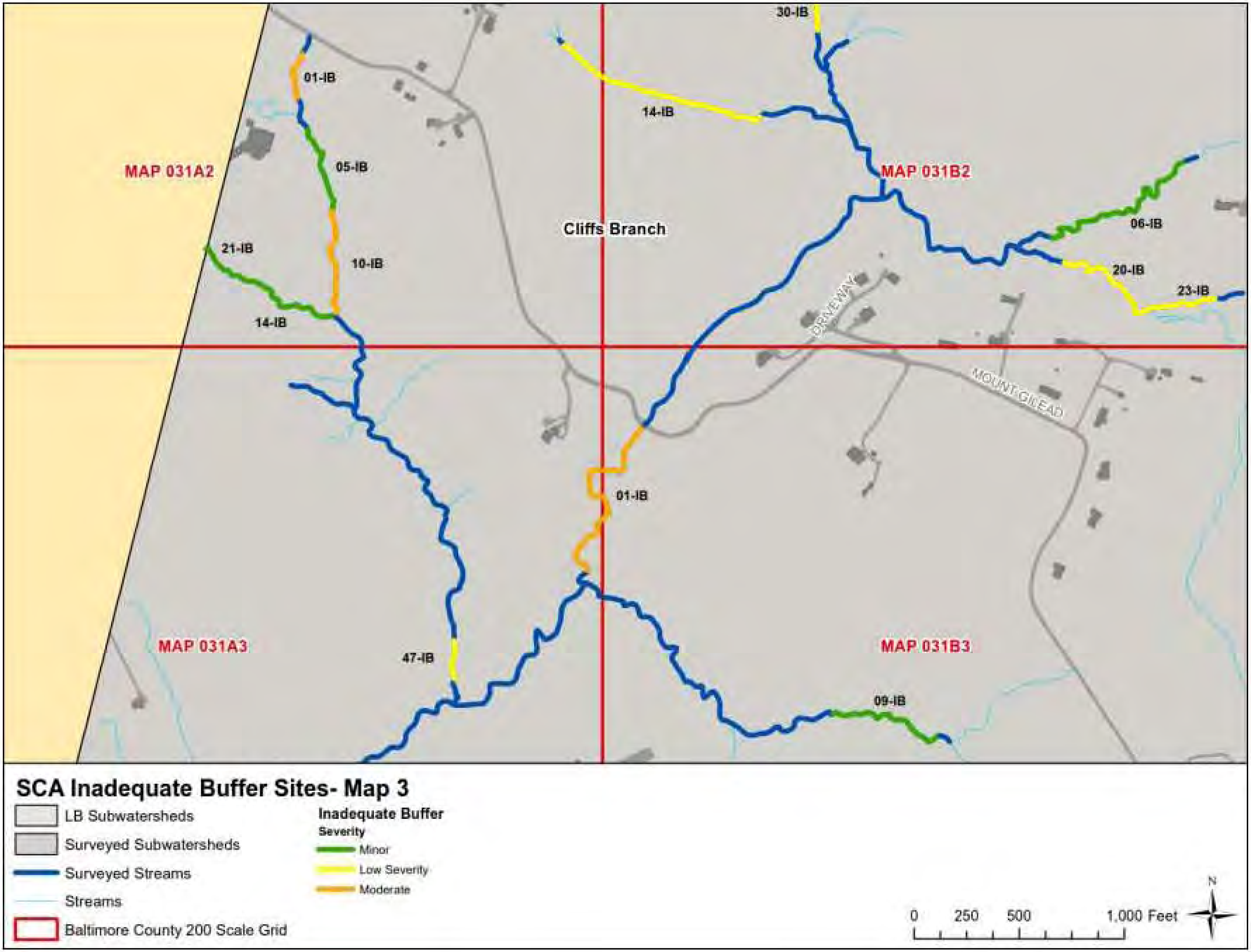

Figure 9: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 3

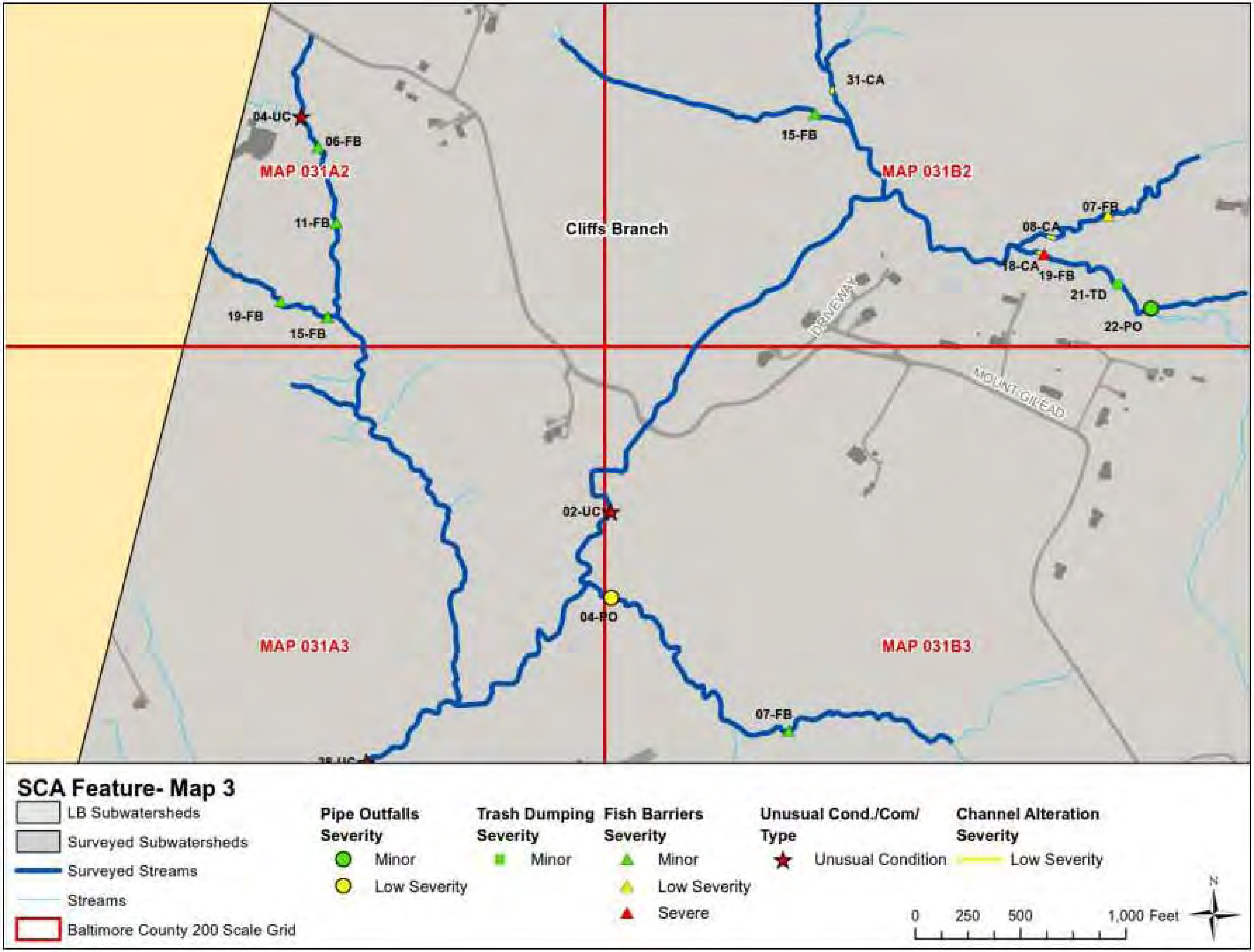

Figure 10: Location of Other SCA Problem Sites in Liberty Reservoir: Map 3

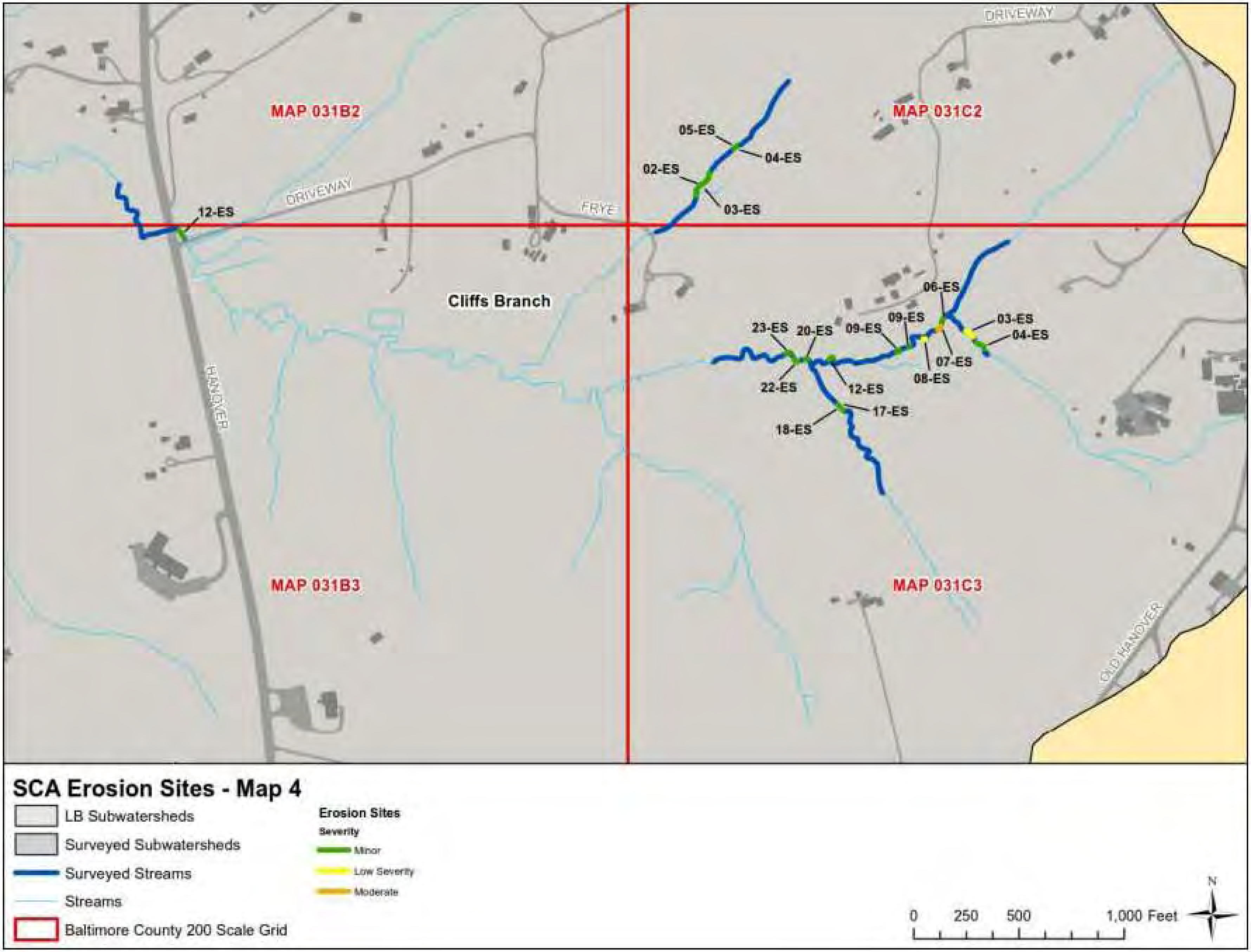

Figure 11: Location of Erosion Sites in Liberty Reservoir: Map 4

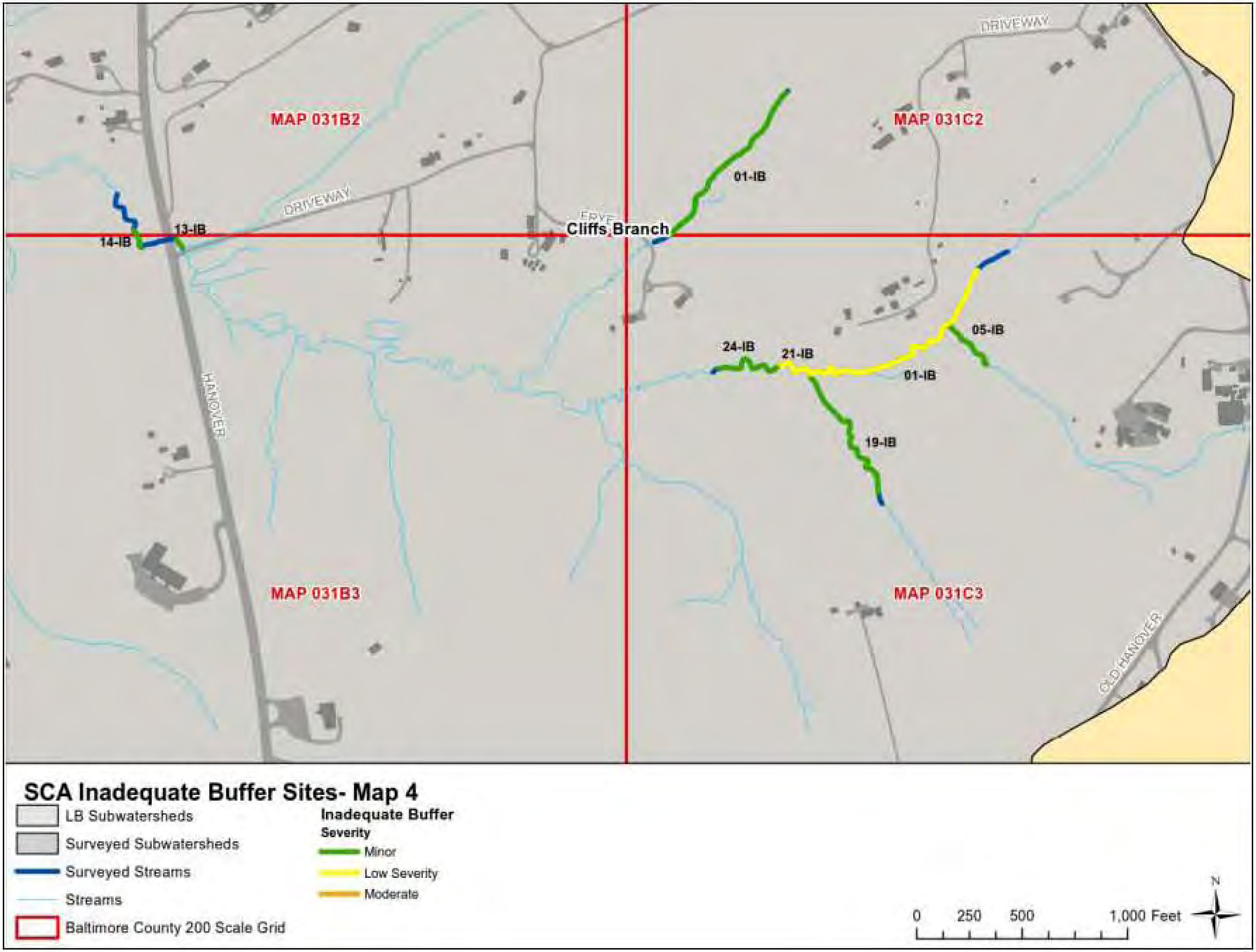

Figure 12: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 4

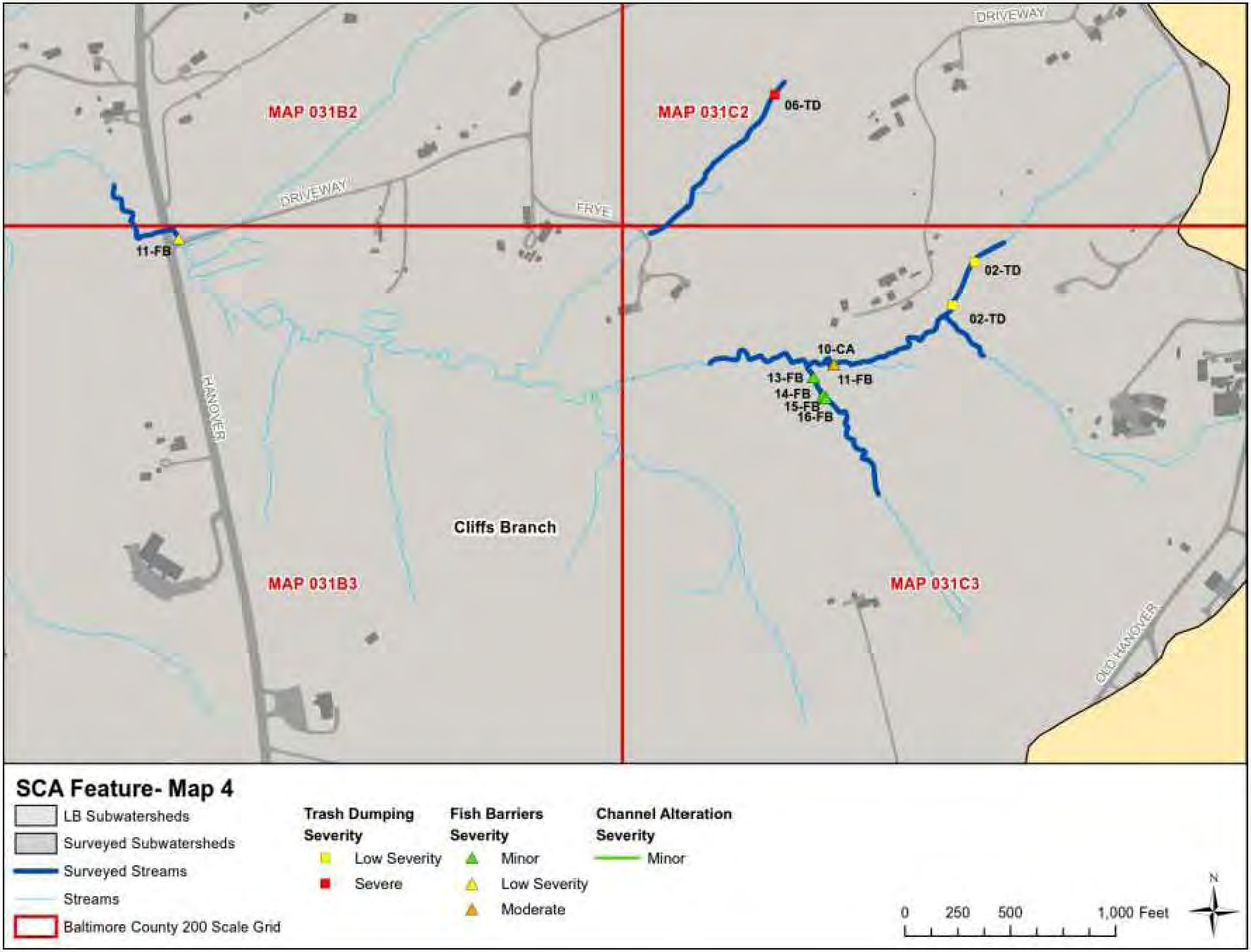

Figure 13: Location of Other SCA Problem Sites in Liberty Reservoir: Map 4

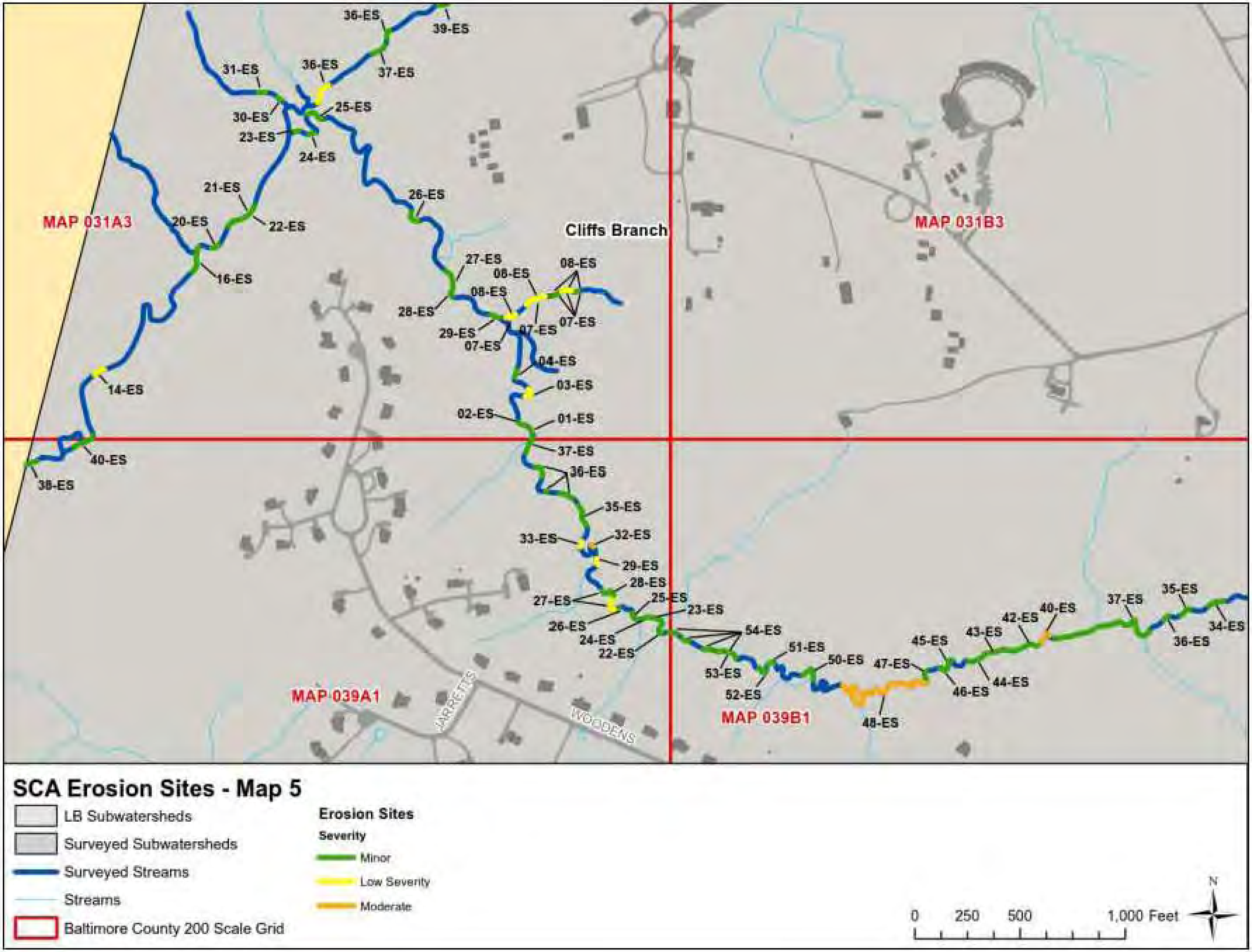

Figure 14: Location of Erosion Sites in Liberty Reservoir: Map 5

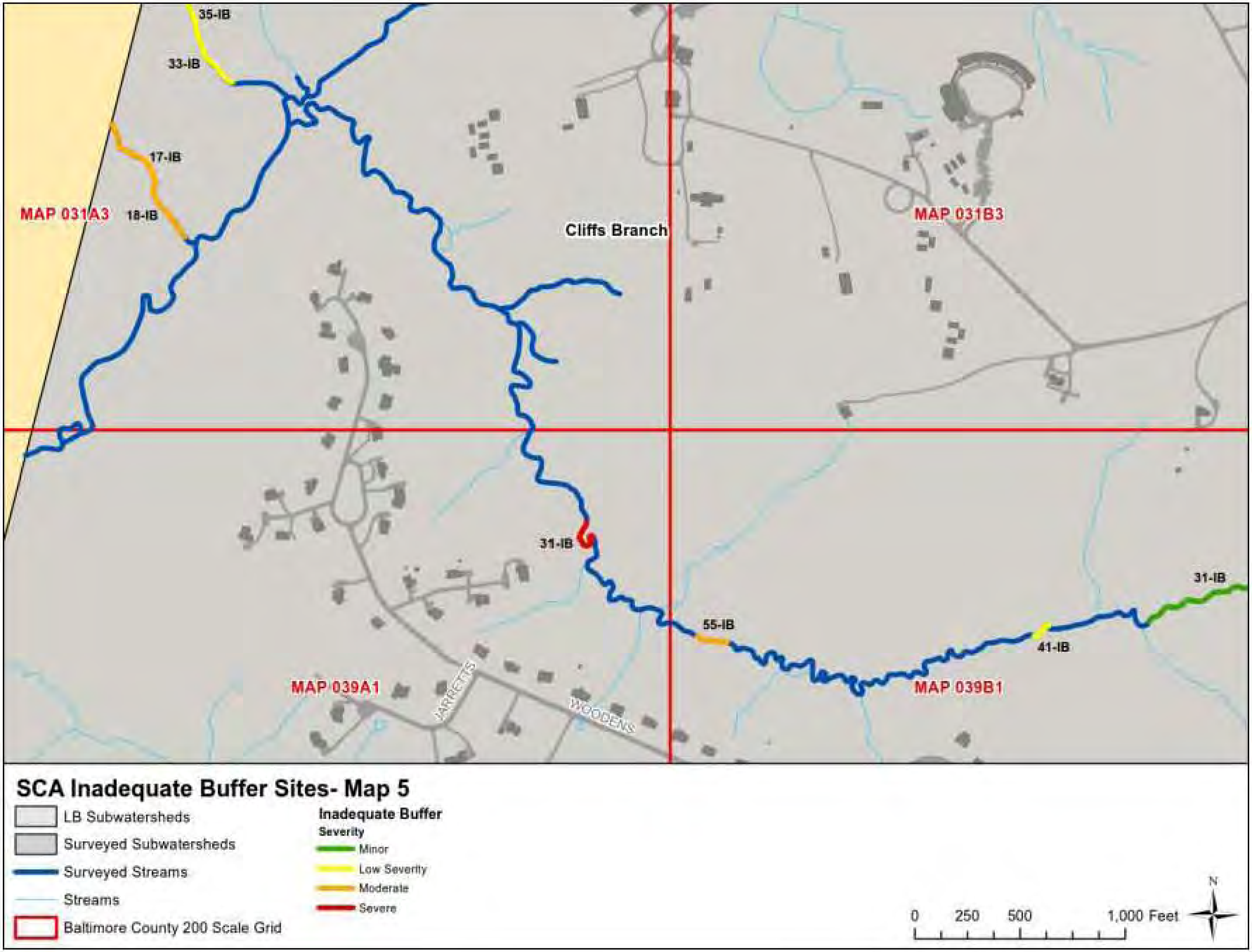

Figure 15: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 5

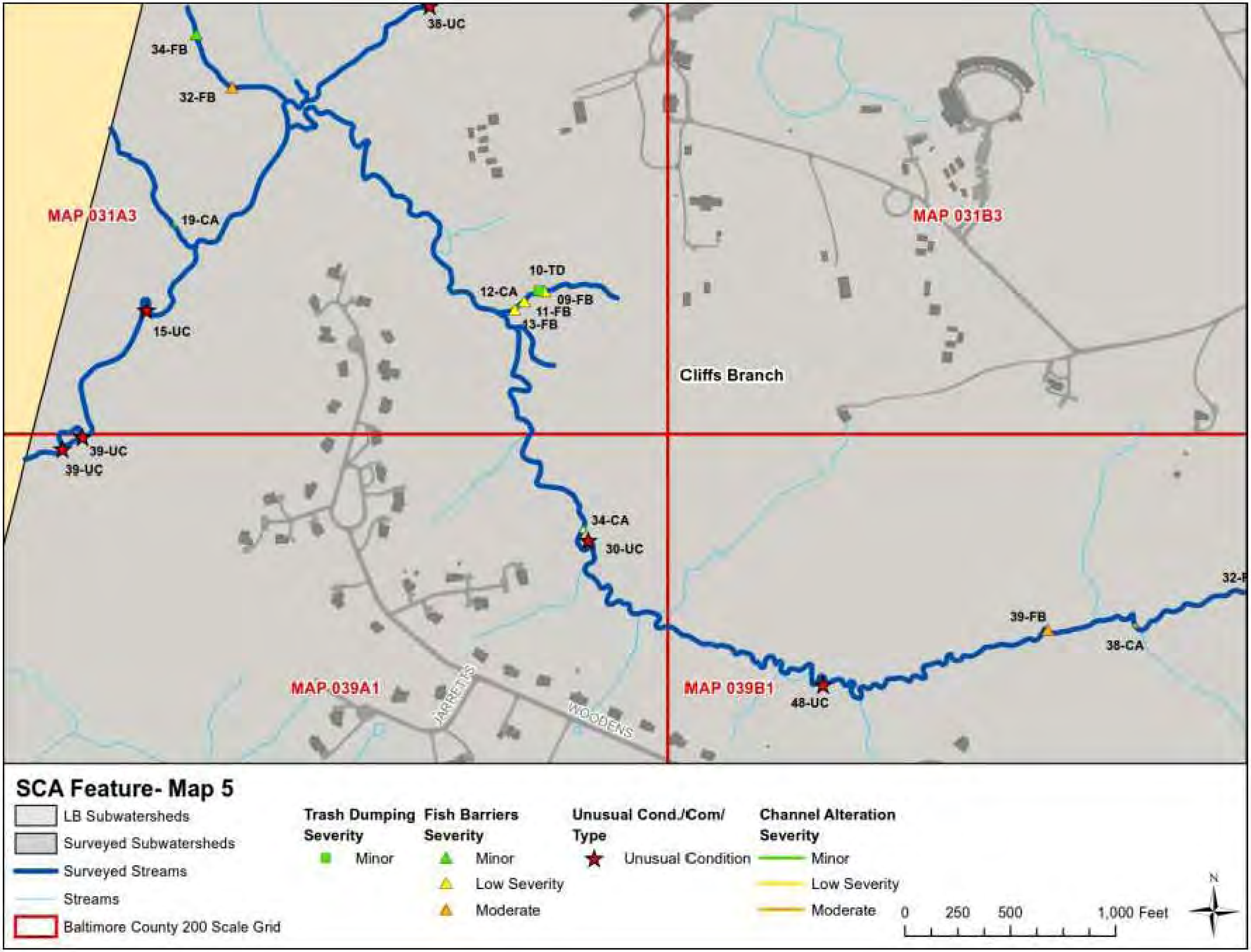

Figure 16: Location of Other SCA Problem Sites in Liberty Reservoir: Map 5

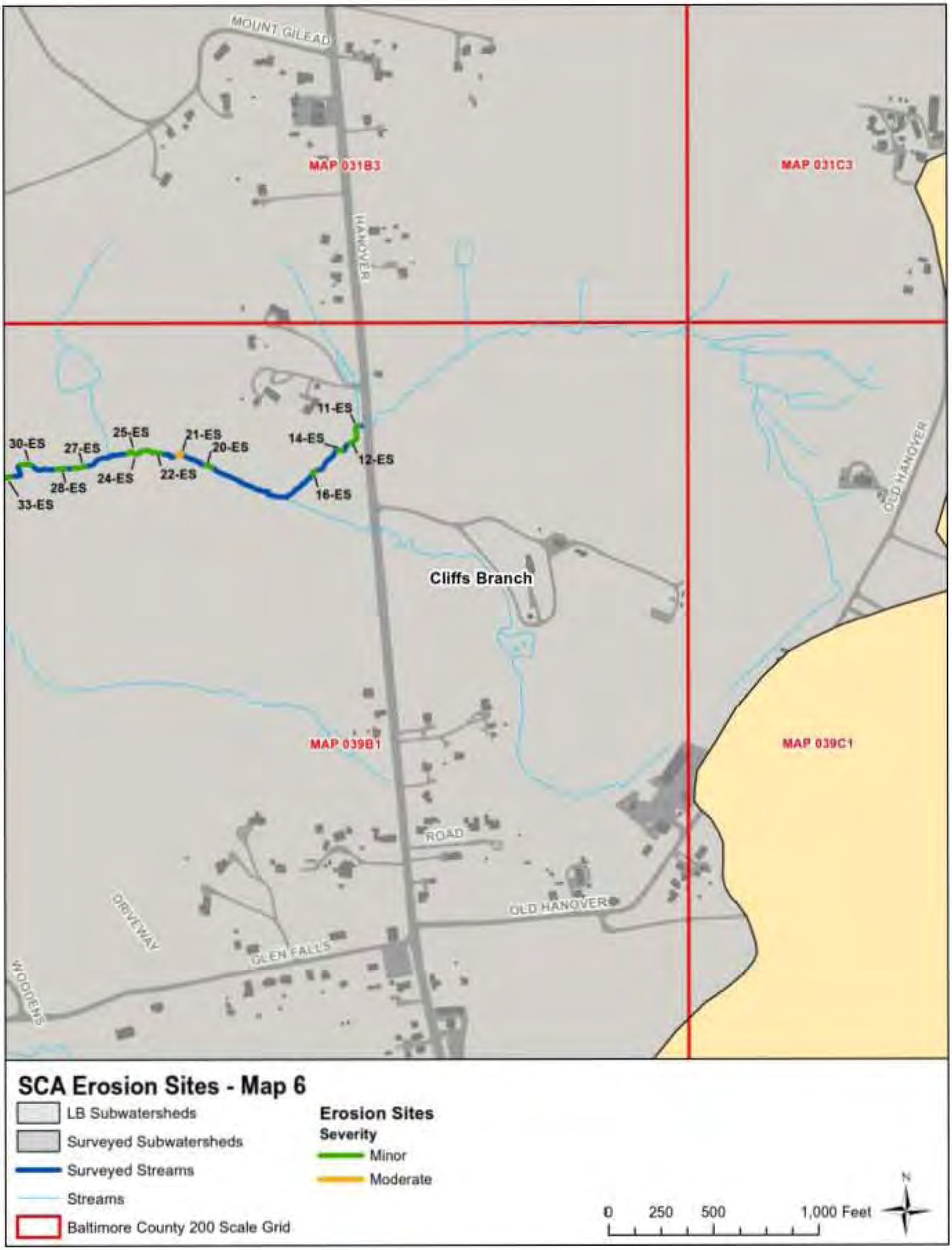

Figure 17: Location of Erosion Sites in Liberty Reservoir: Map 6

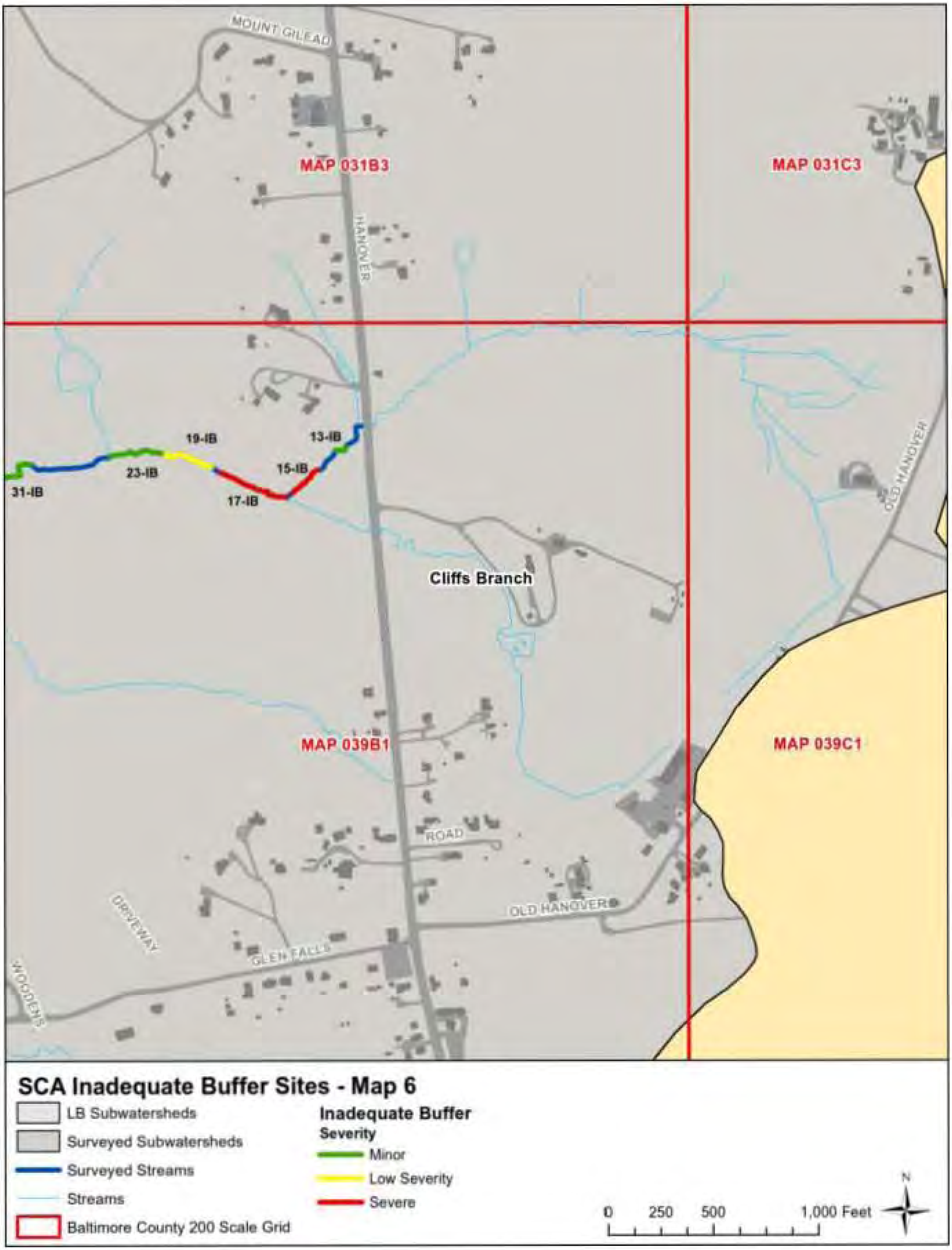

Figure 18: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 6

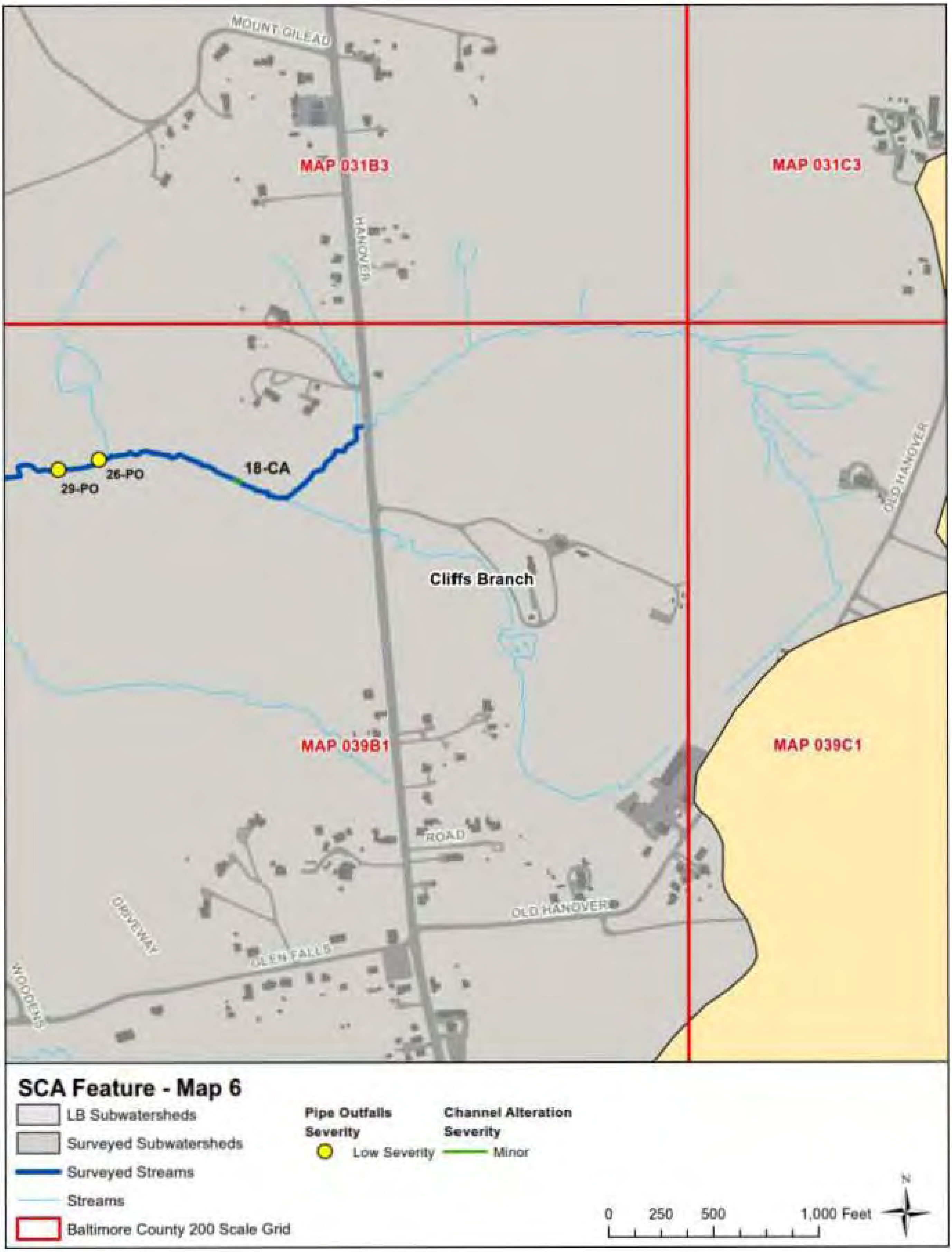

Figure 19: Location of Other SCA Problem Sites in Liberty Reservoir: Map 6

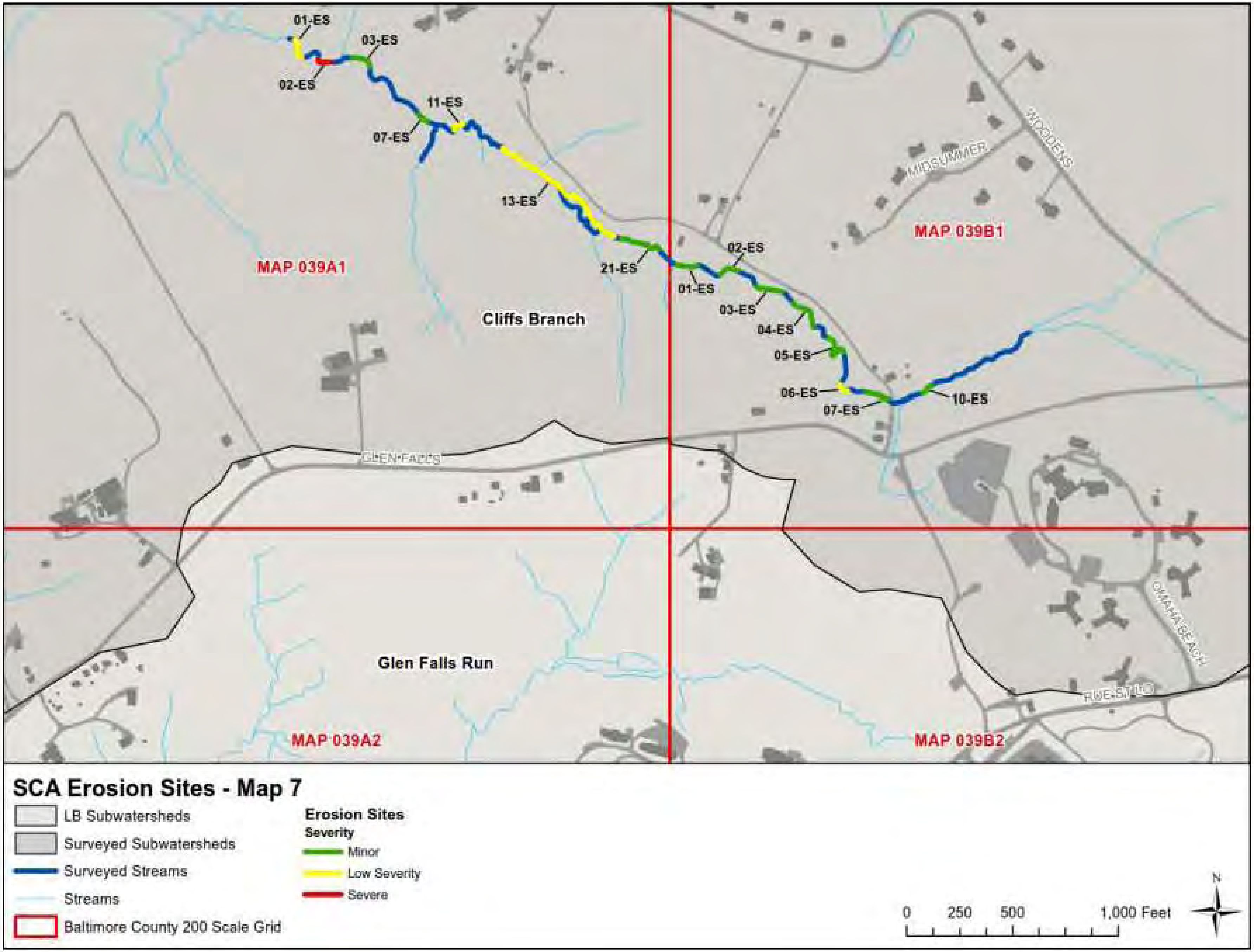

Figure 20: Location of Erosion Sites in Liberty Reservoir: Map 7

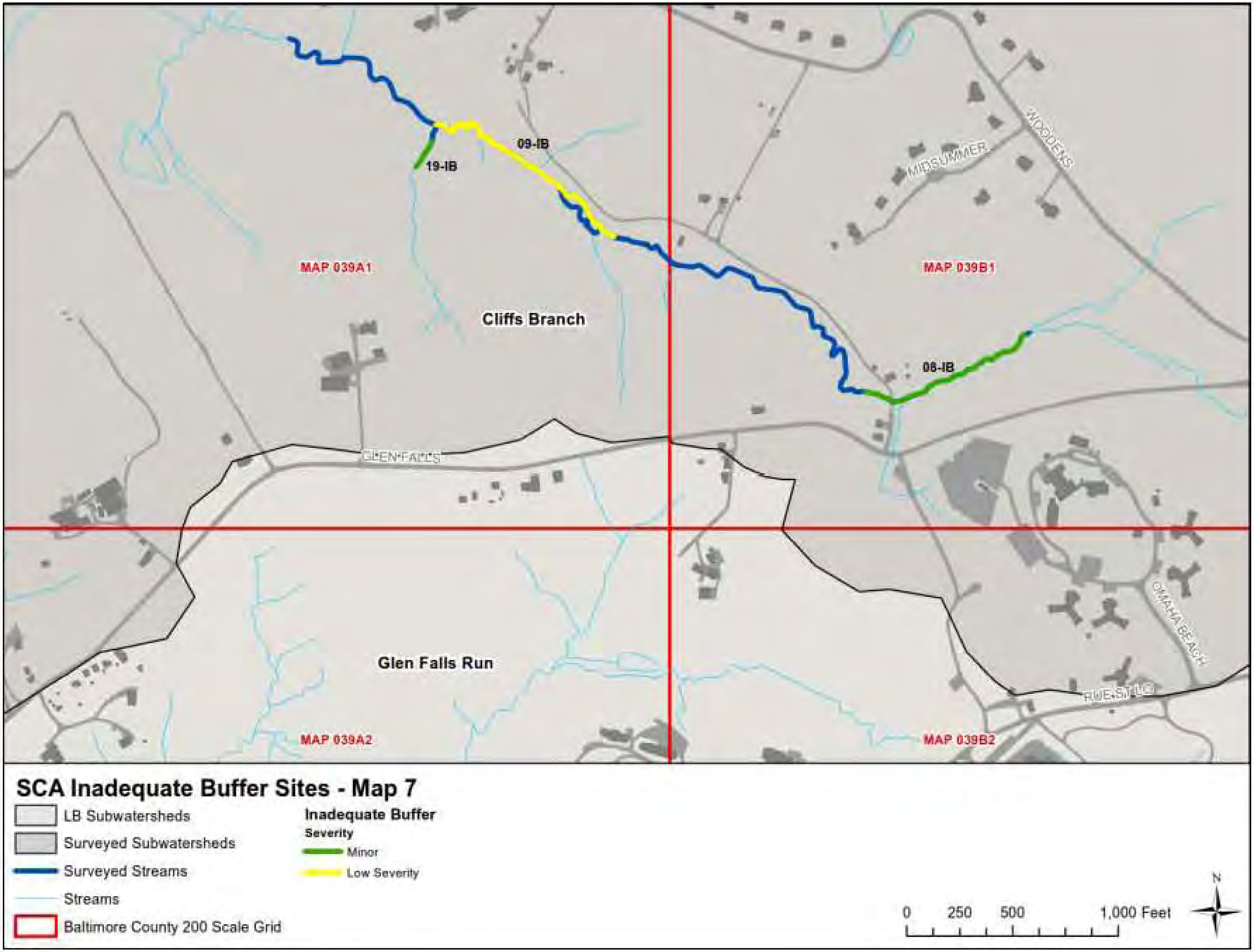

Figure 21: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 7

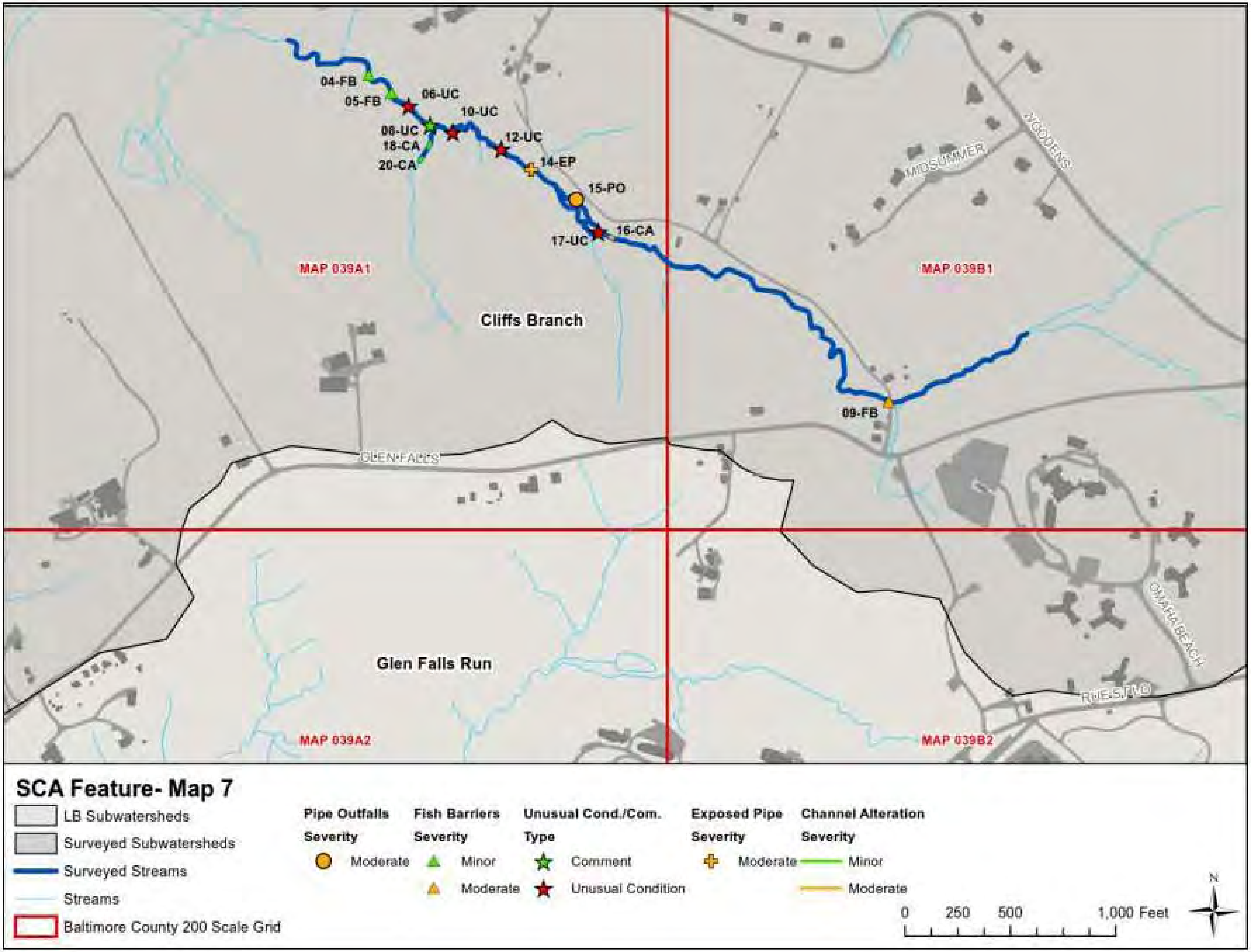

Figure 22: Location of Other SCA Problem Sites Liberty Reservoir: Map 7

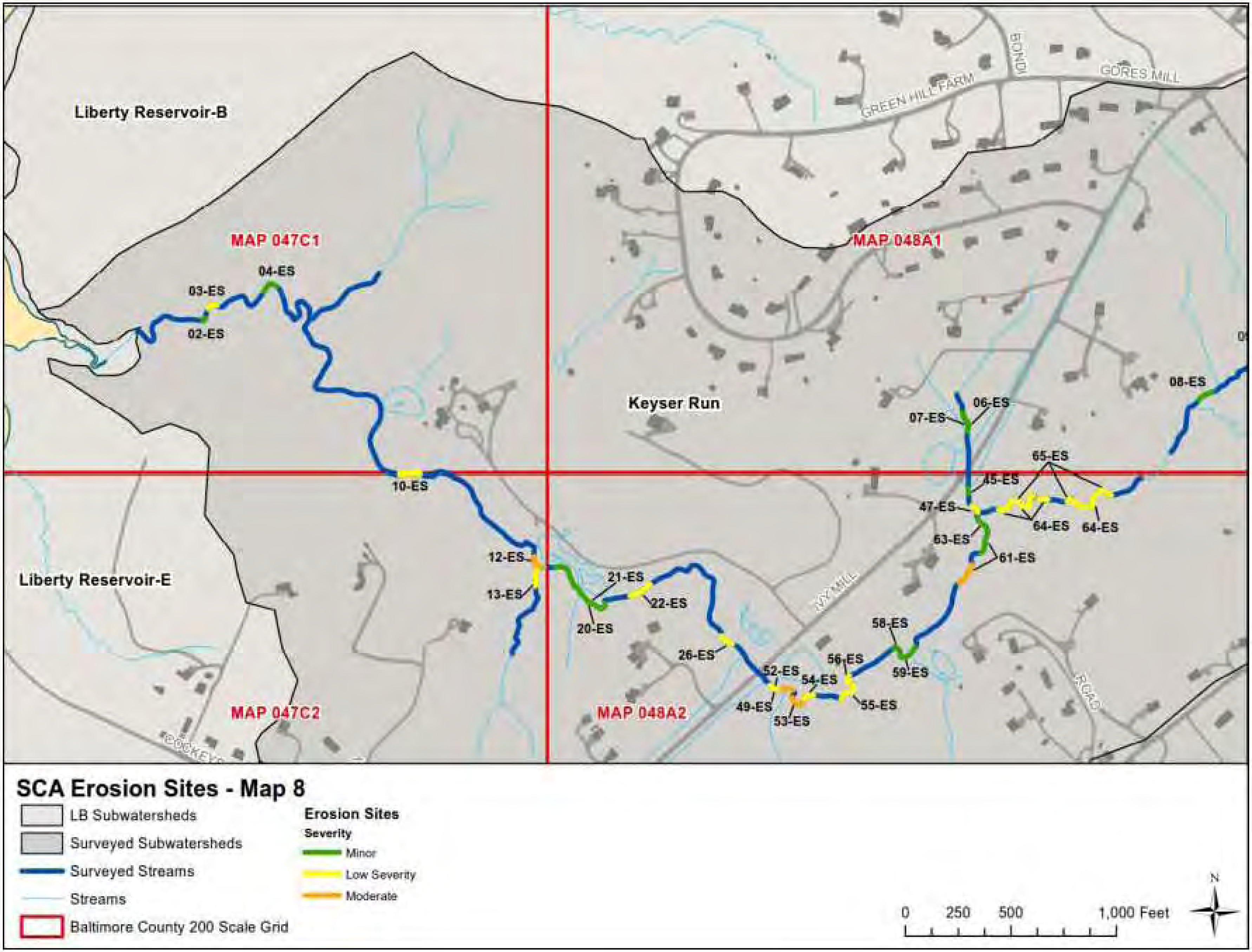

Figure 23: Location of Erosion Sites in Liberty Reservoir: Map 8

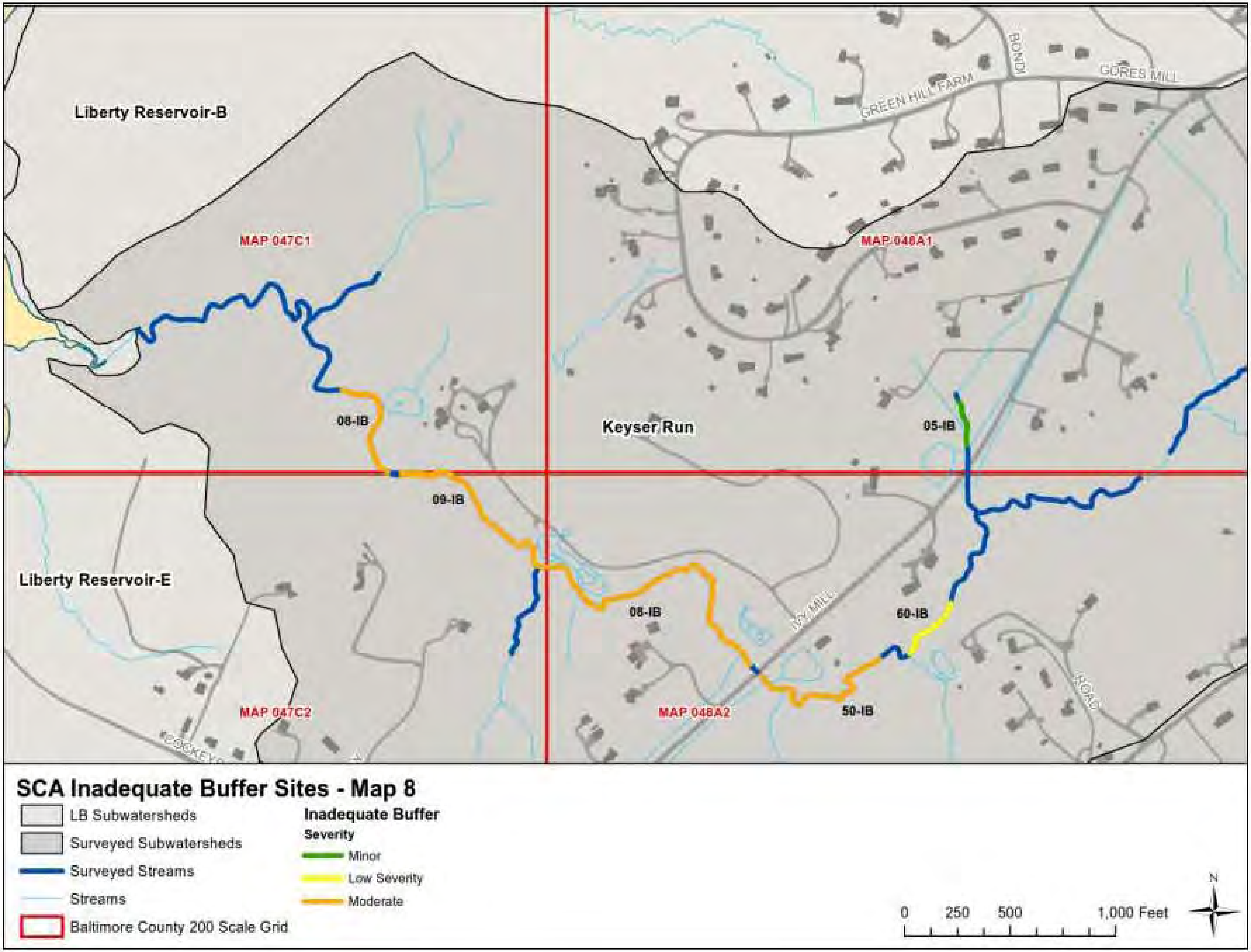

Figure 24: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 8

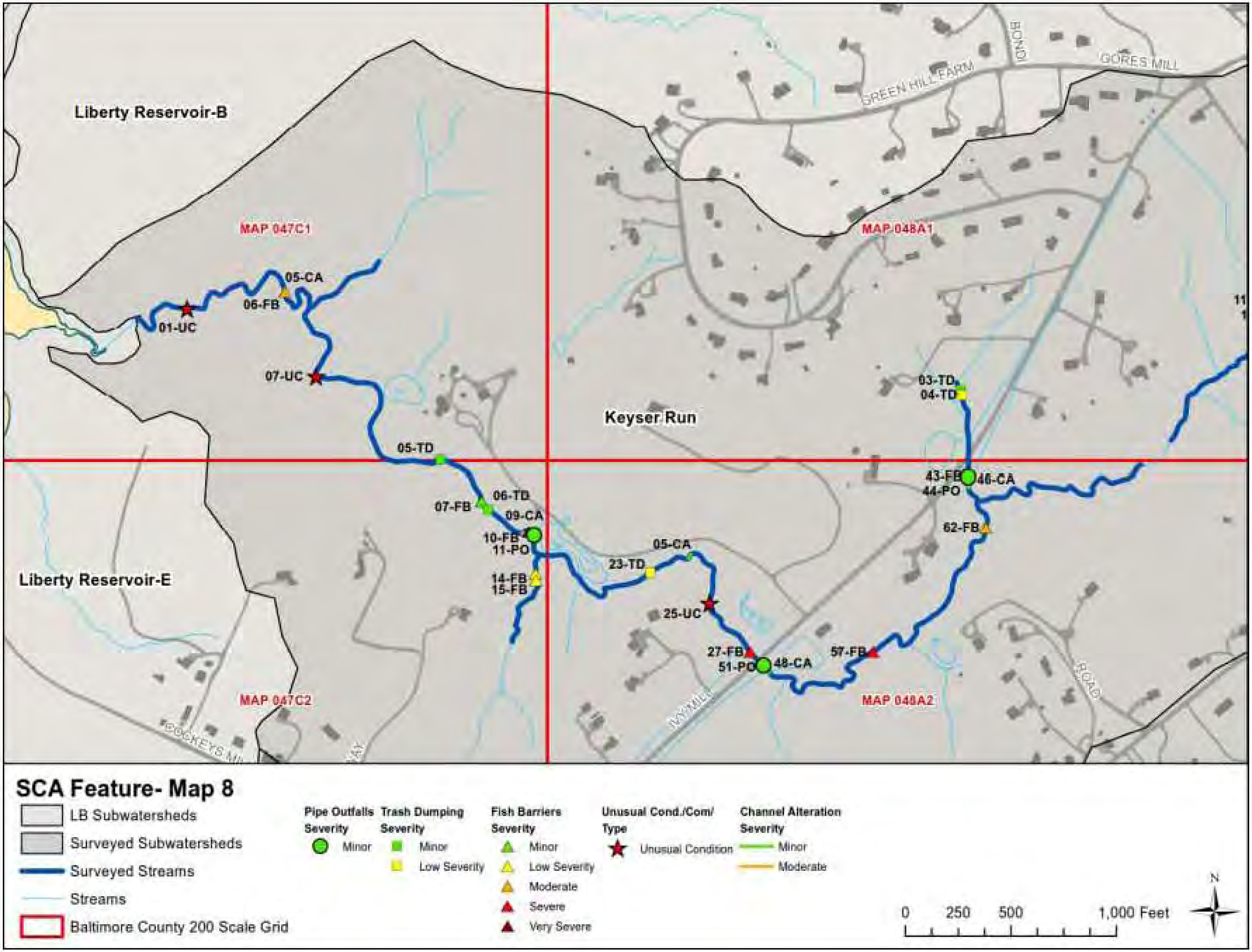

Figure 25: Location of Other SCA Problem Sites in Liberty Reservoir: Map 8

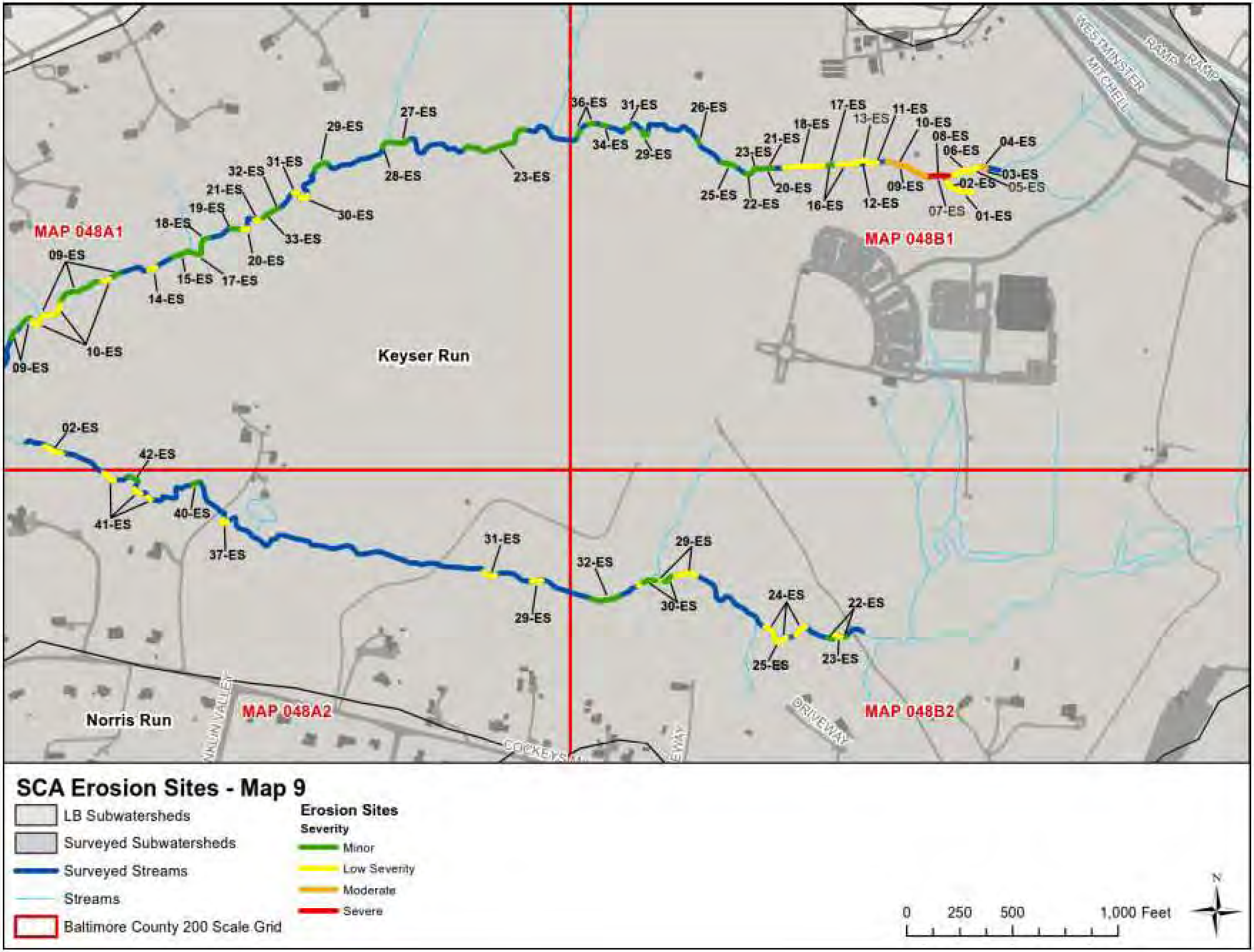

Figure 26: Location of Erosion Sites in Liberty Reservoir: Map 9

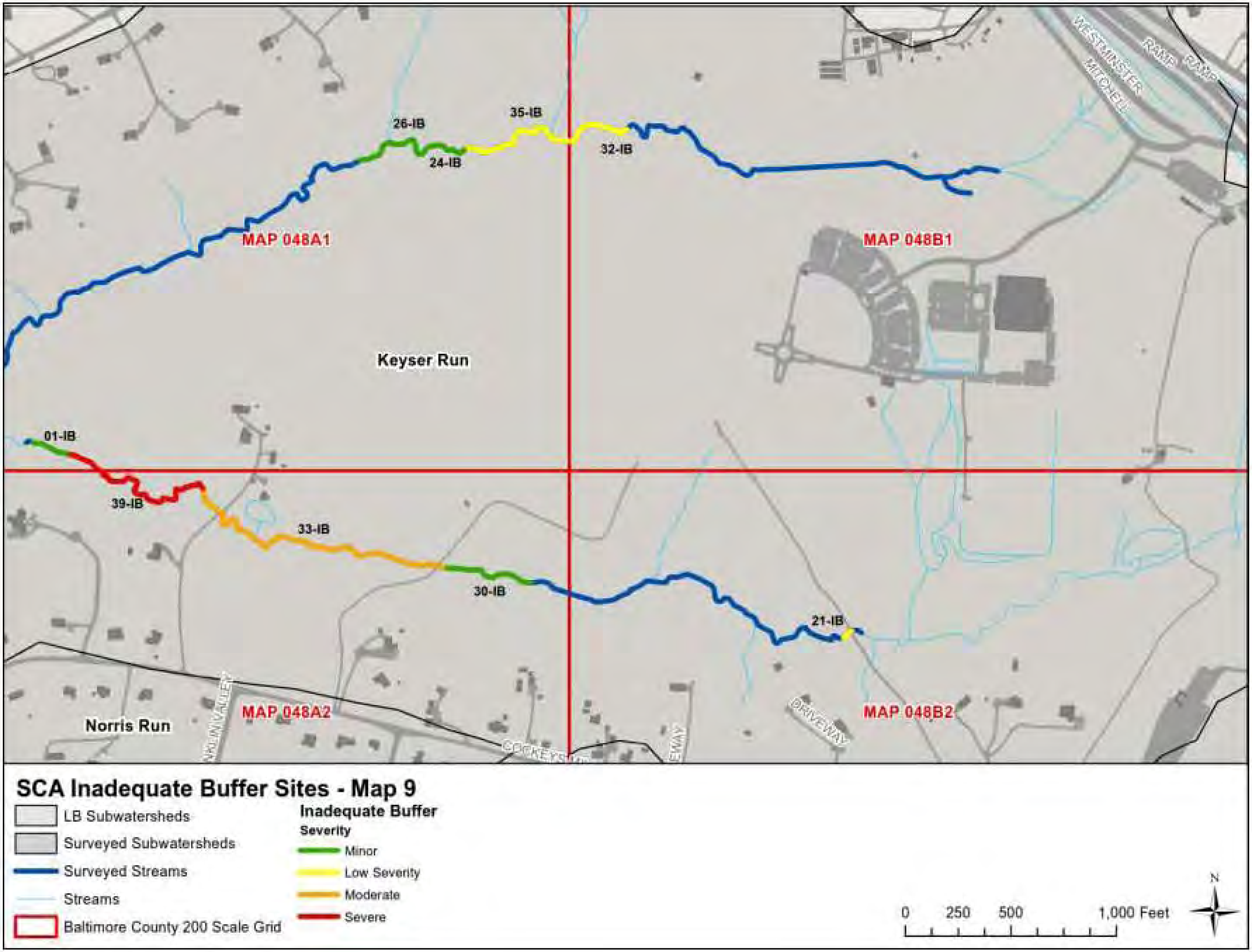

Figure 27: Location of Inadequate Buffer in Liberty Reservoir: Map 9

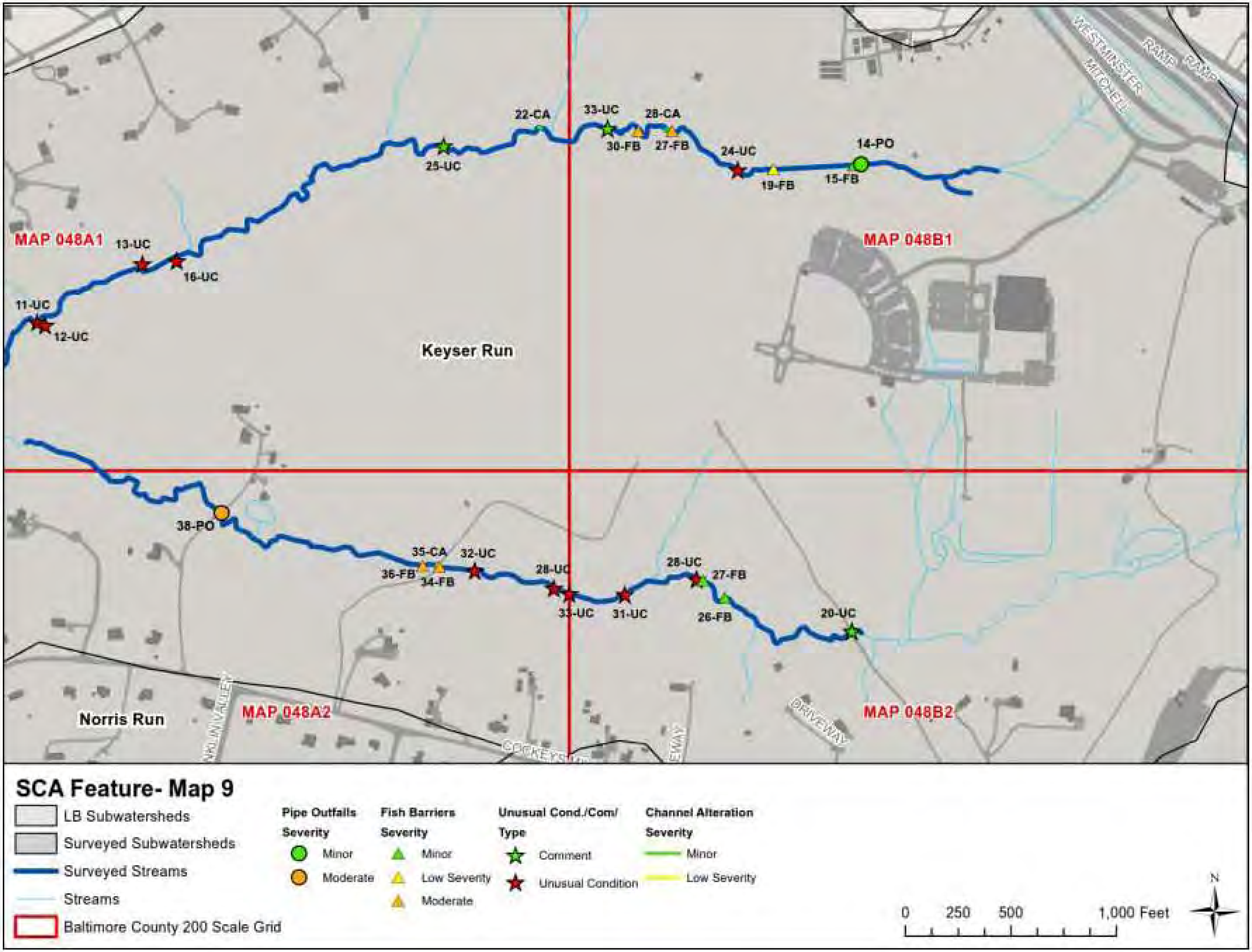

Figure 28: Location of Other SCA Problem Sites in Liberty Reservoir: Map 9

Figure 29: Location of Erosion Sites in Liberty Reservoir: Map 10

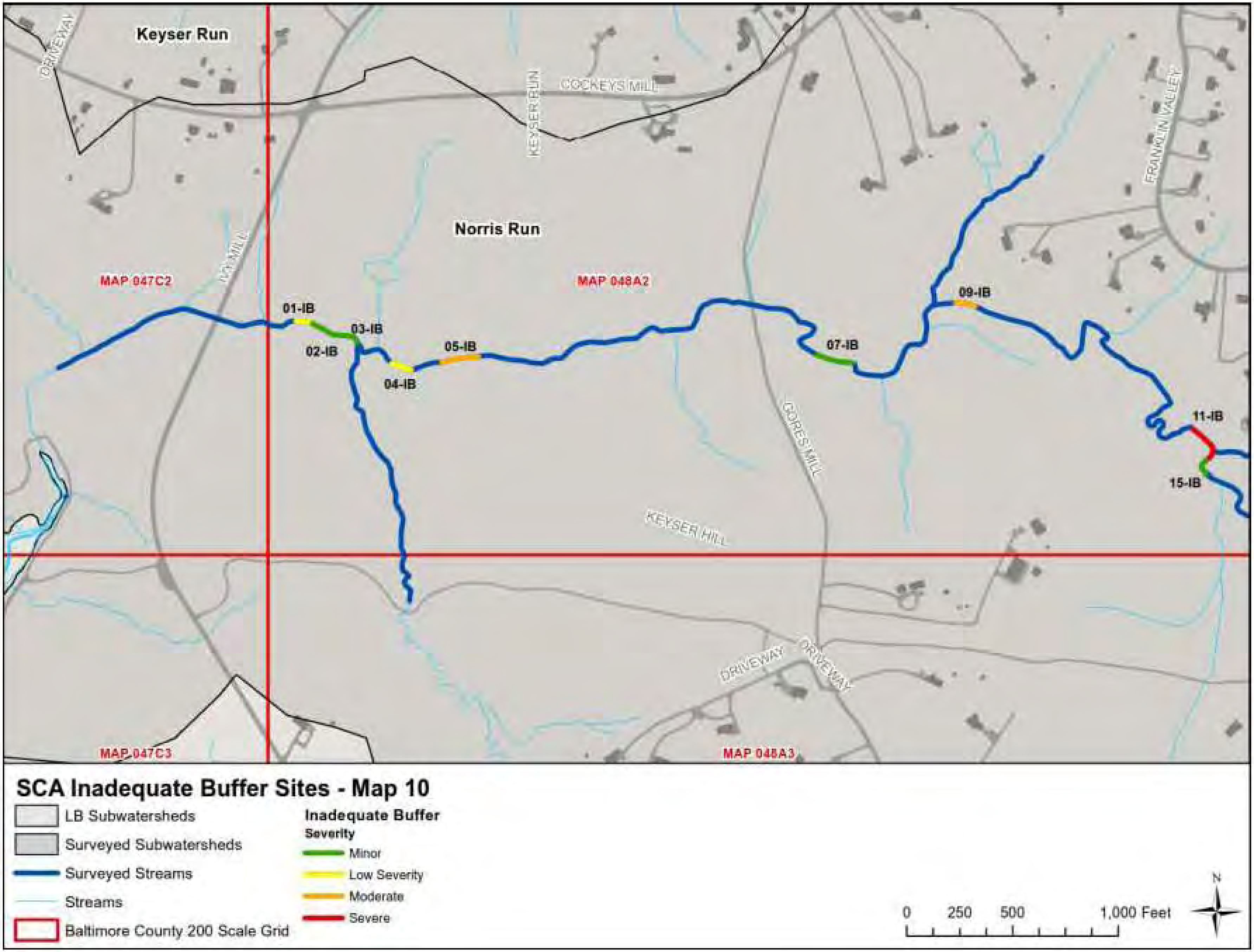

Figure 30: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 10

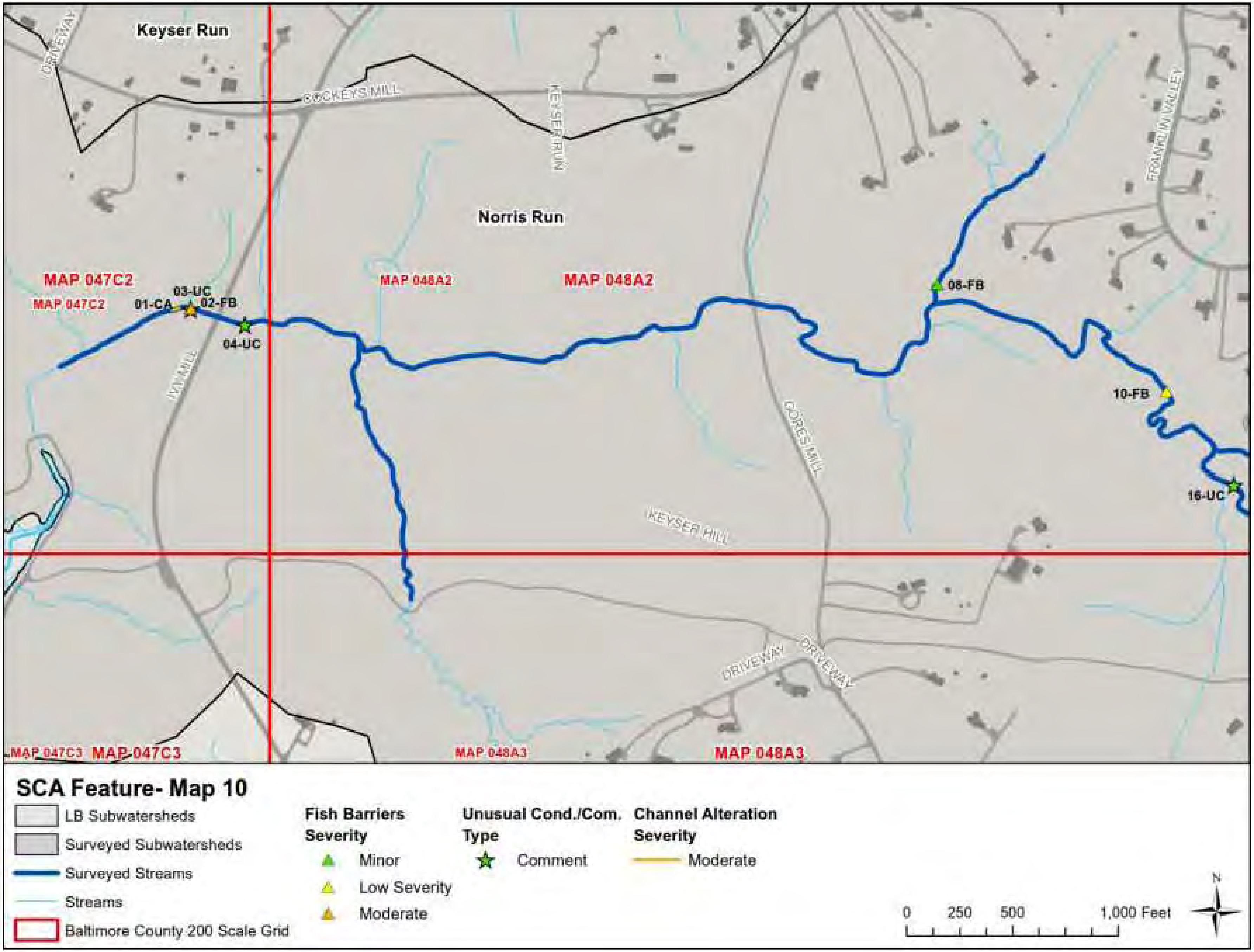

Figure 31: Location of SCA Problem Sites in Liberty Reservoir: Map 10

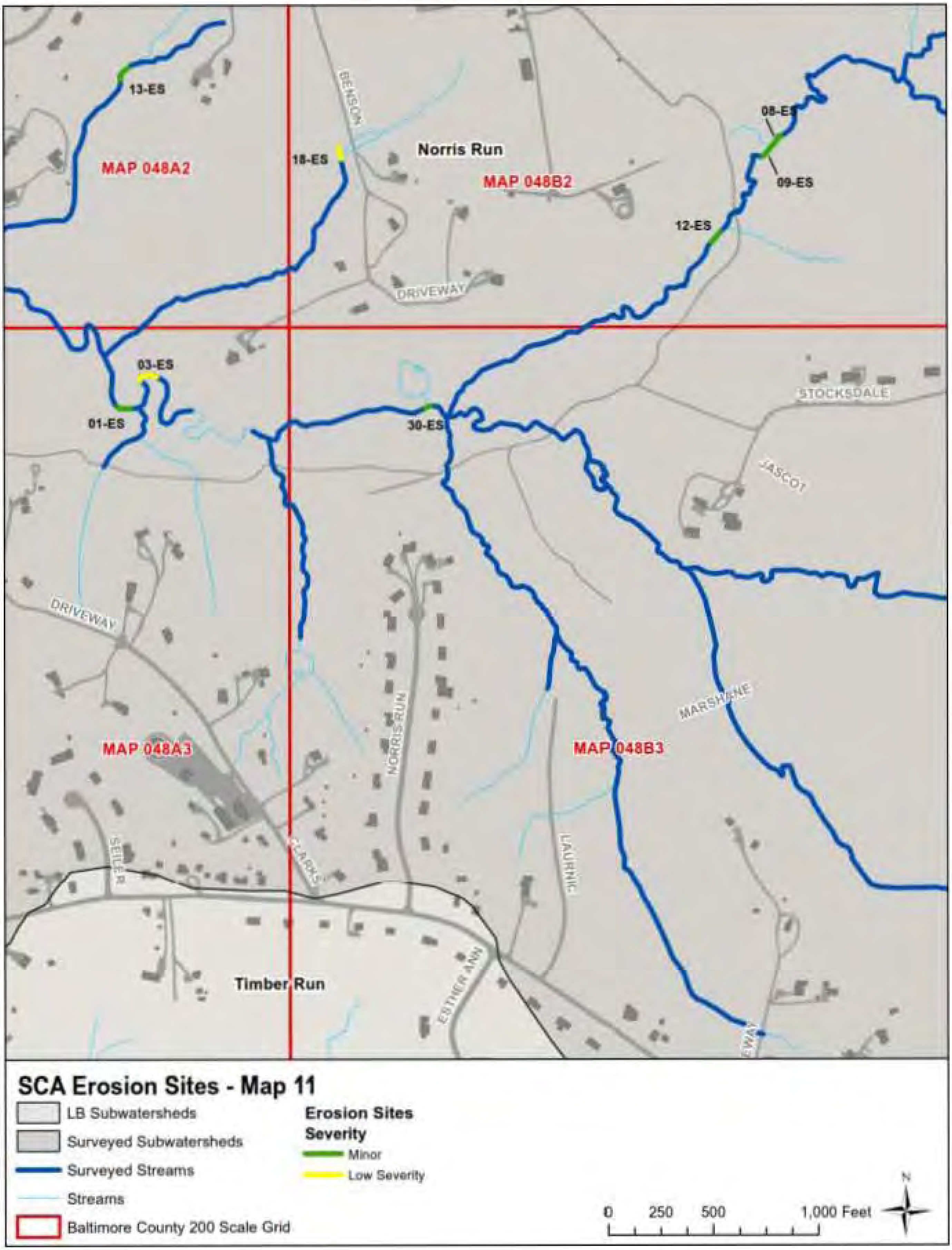

Figure 32: Location of Erosion Sites in Liberty Reservoir: Map 11

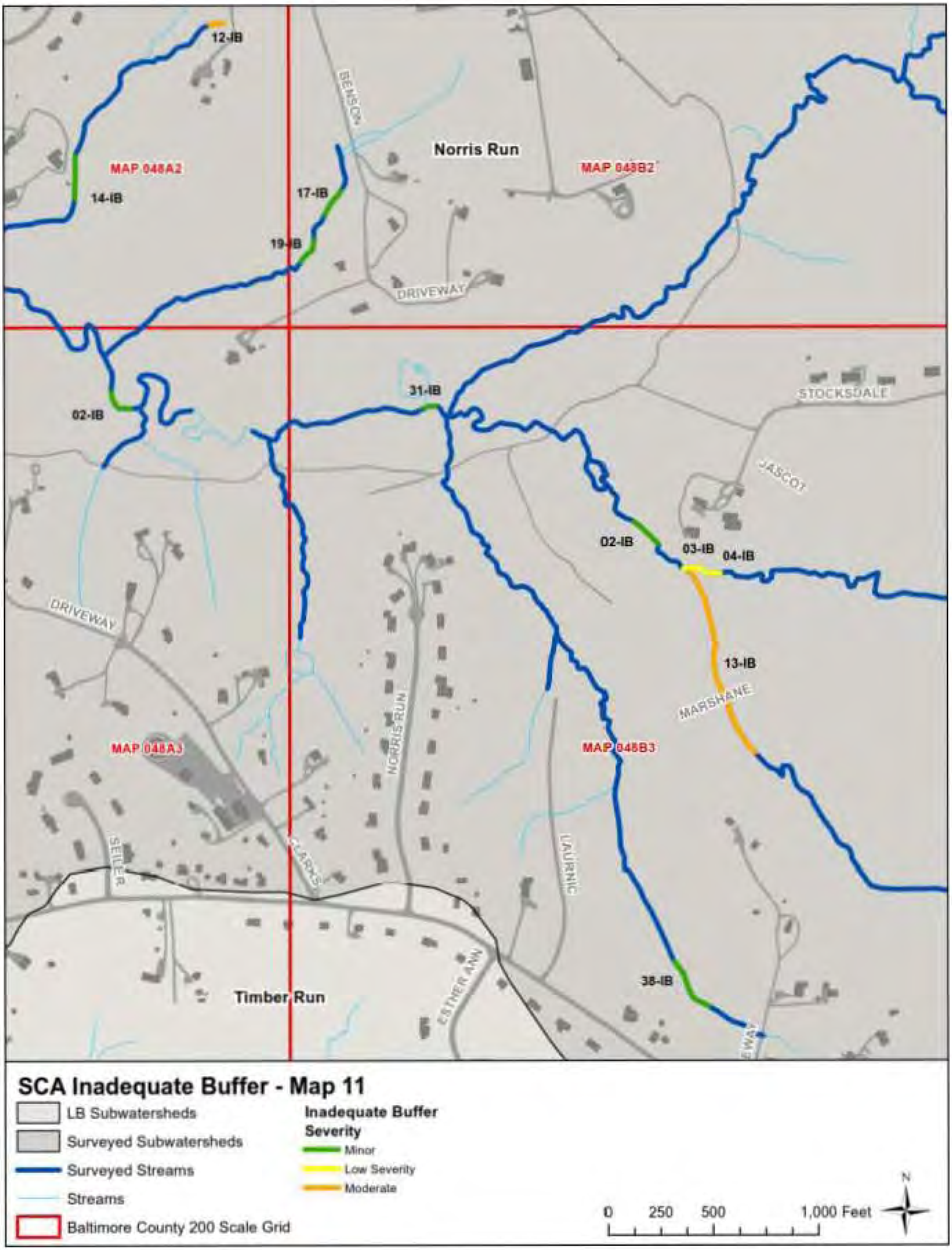

Figure 33: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 11

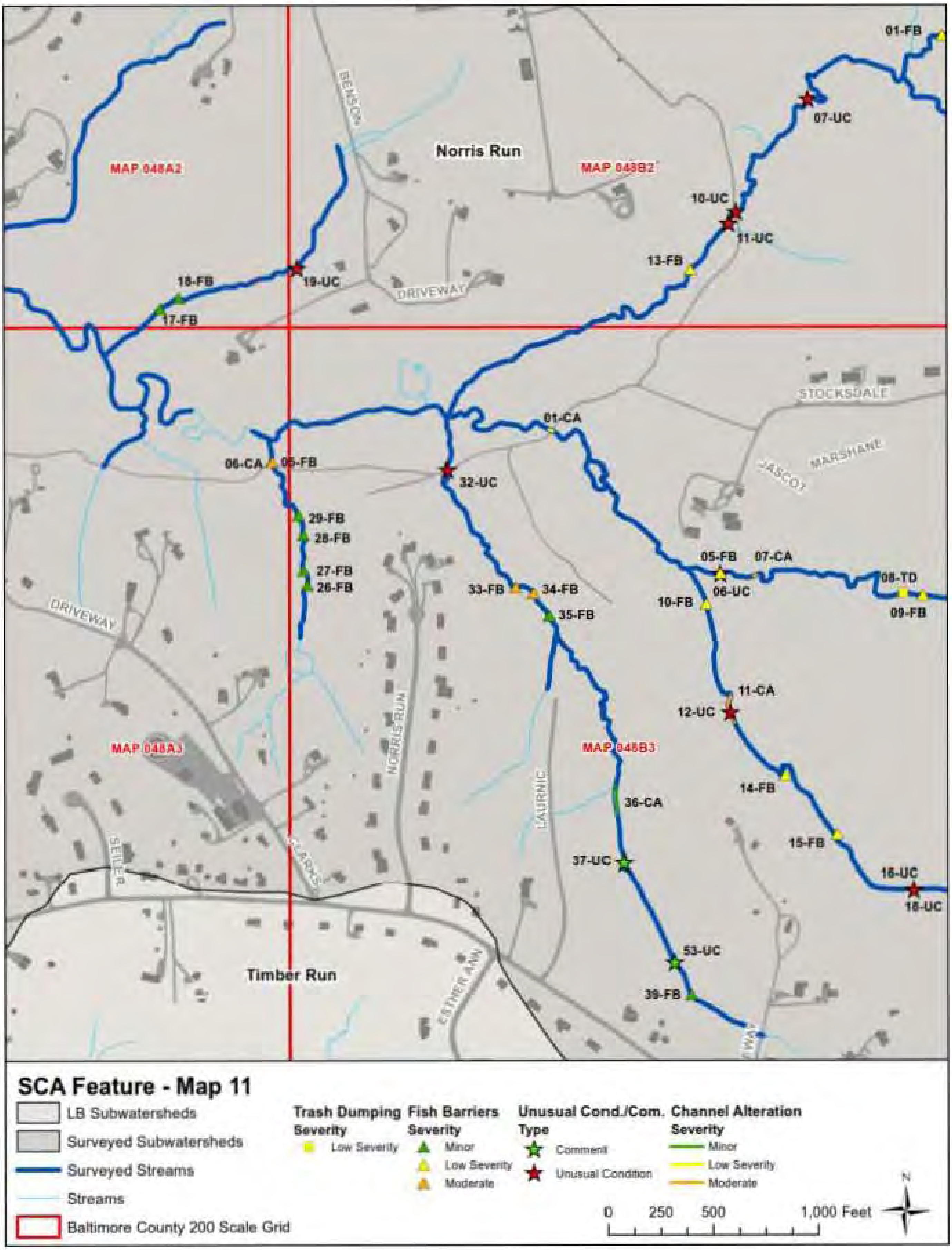

Figure 34: Location of Other SCA Problem Sites in Liberty Reservoir: Map 11

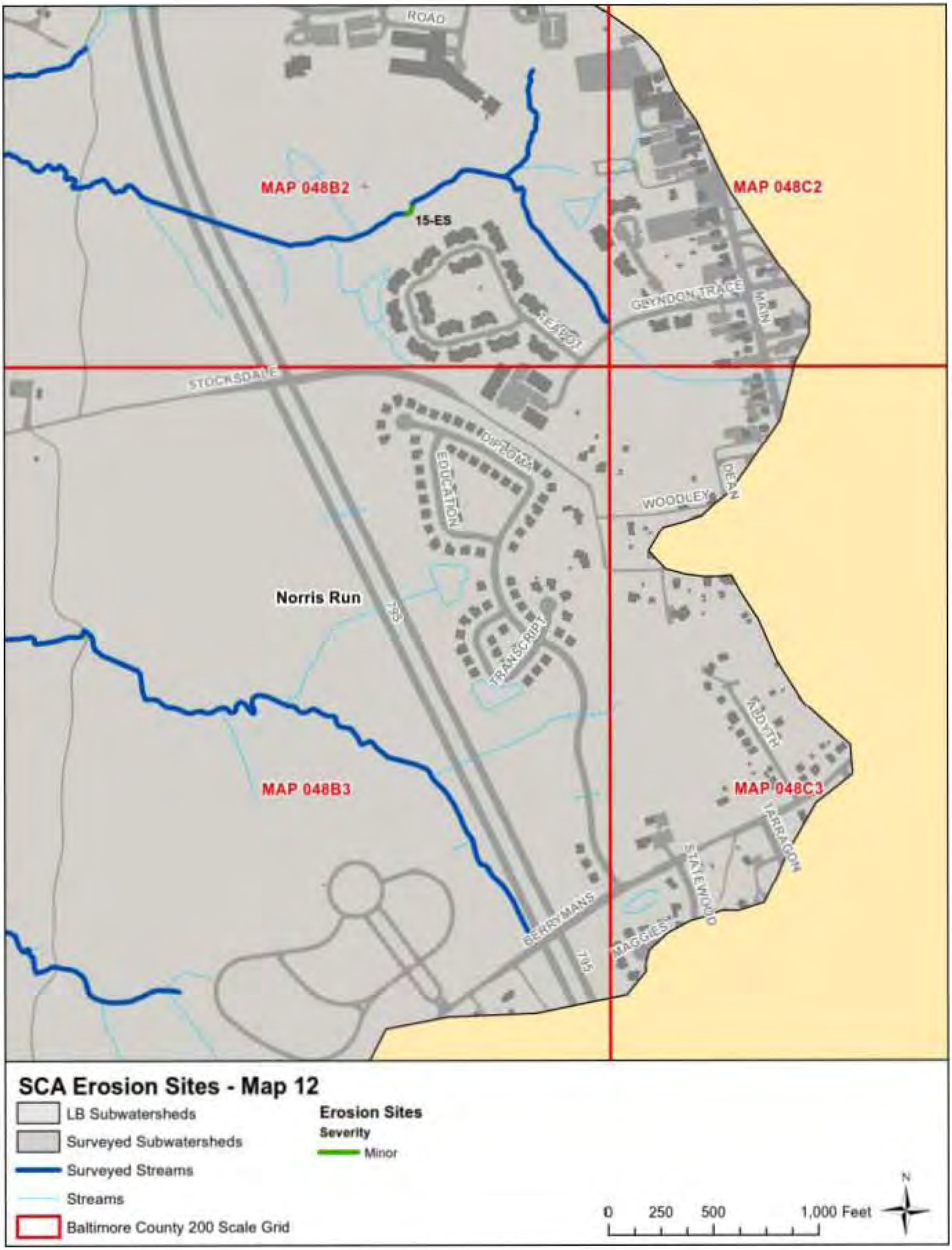

Figure 35: Location of Erosion Sites in Liberty Reservoir: Map 12

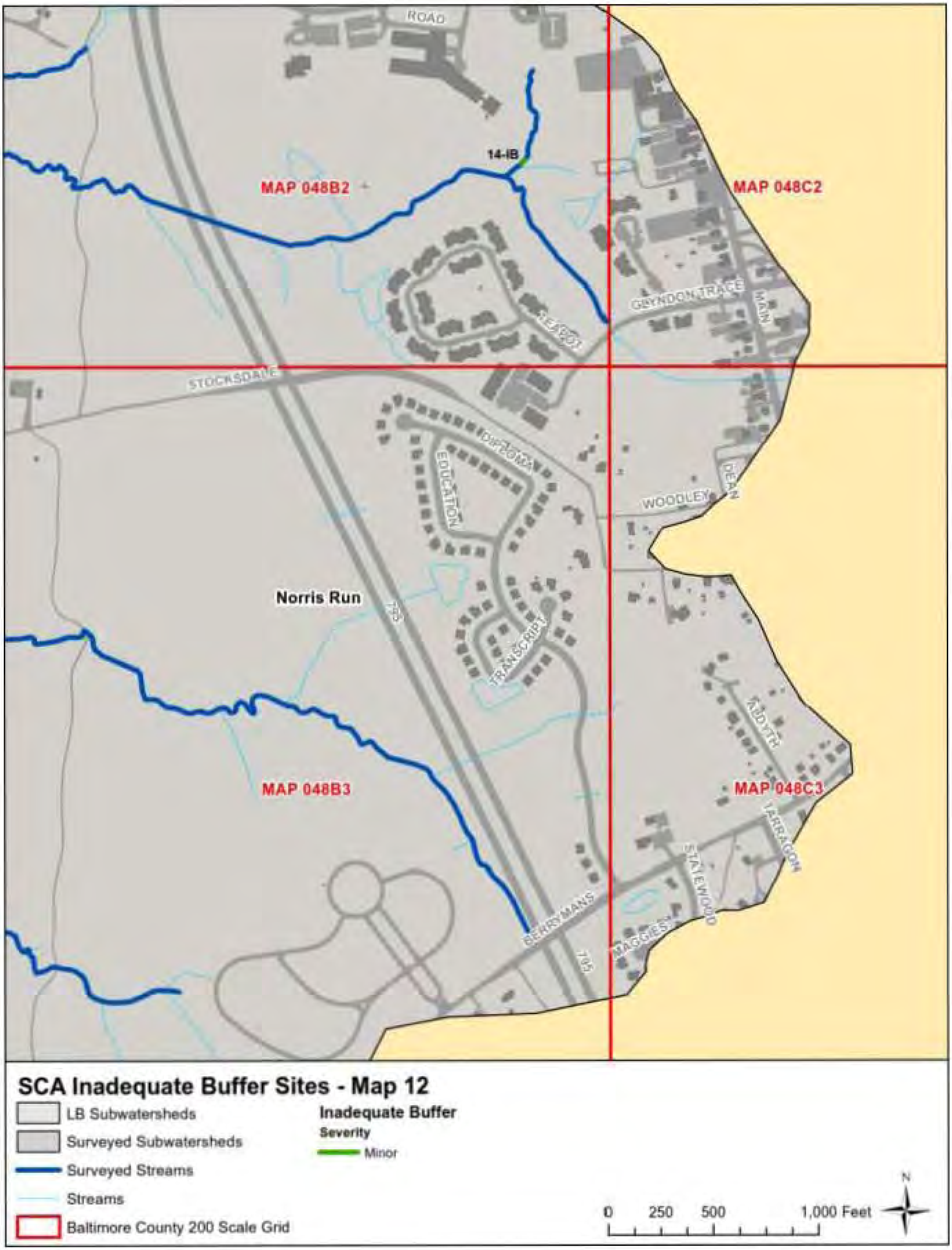

Figure 36: Location of Inadequate Buffer Sites in Liberty Reservoir: Map 12

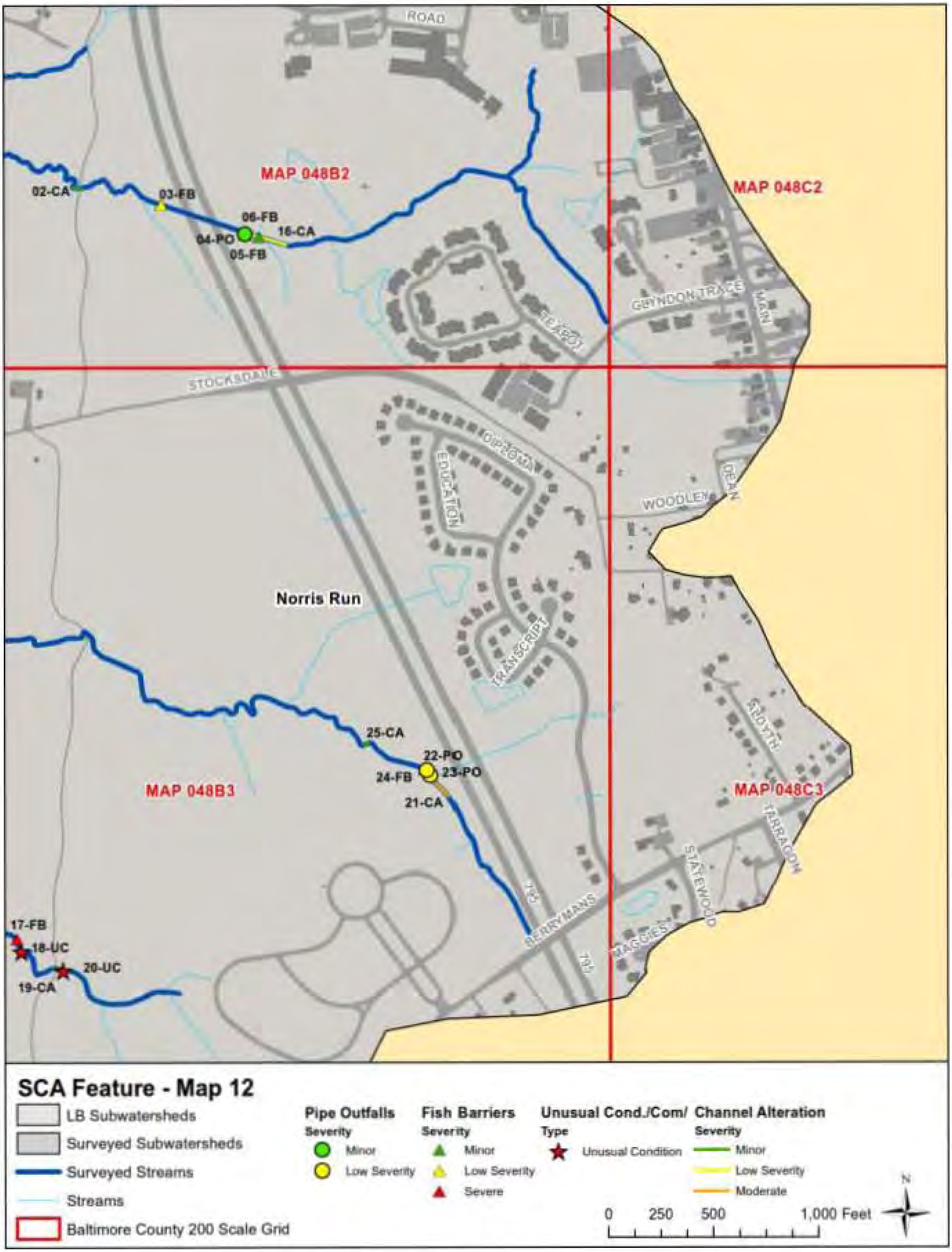

Figure 37: Location of Other SCA Problem Sites in Liberty Reservoir: Map 12

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BANK	CHANNEL CONDITION	CAUSE	AVG. EXPOSED BANK HEIGHT (FT)	LAND USE (LEFT)	LAND USE (RIGHT)	THREAT TO INFRA-STRUCTURE	LENGTH (FT)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039B1	01-ES	RB	Stage I Incision	Bend at Steep Slope	4	Forest	Shrubs Small Trees	N	101	Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039B1	02-ES	RB	Stage I Incision	Bend at Steep Slope	5	Forest	Forest	N	95	Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039B1	03-ES	LB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	125	Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039B1	04-ES	LB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	167	Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039B1	05-ES	RB	Stage I Incision	Bend at Steep Slope	5	Forest	Forest	N	181	Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039B1	06-ES	LB	Stage I Incision	Bend at Steep Slope	5	Forest	Forest	N	55	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039B1	07-ES	RB	Stage I Incision	Bend at Steep Slope	3	Forest	Pasture	N	112	Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039B1	10-ES	RB	Stage I Incision	Bend at Steep Slope	3	Shrubs Small Trees	Pasture	N	58	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	11-ES	RB	Stage II Widening	Bend at Steep Slope	6	Forest	Shrubs Small Trees	N	68	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	12-ES	LB	Stage II Widening	Bend at Steep Slope	3	Shrubs Small Trees	Forest	N	38	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	14-ES	LB	Stage II Widening	Bend at Steep Slope	4	Other	Other	N	24	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	16-ES	RB	Stage II Widening	Land Use Change	5	Shrubs Small Trees	Crop Field	N	21	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	20-ES	RB	Stage I Incision	Bend at Steep Slope	4	Forest	Crop Field	N	33	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	21-ES	RB	Stage I Incision	Bend at Steep Slope	3	Forest	Crop Field	N	26	Moderate
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	22-ES	RB	Stage II Widening	Bend at Steep Slope	3	Forest	Shrubs Small Trees	N	108	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	24-ES	LB	Stage II Widening	Bend at Steep Slope	3	Shrubs Small Trees	Shrubs Small Trees	N	35	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	25-ES	RB	Stage I Incision	Bend at Steep Slope	4	Shrubs Small Trees	Shrubs Small Trees	N	28	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	27-ES	RB	Stage II Widening	Bend at Steep Slope	4	Forest	Shrubs Small Trees	N	53	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	28-ES	RB	Stage II Widening	Bend at Steep Slope	4	Forest	Shrubs Small Trees	N	39	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	30-ES	RB	Stage I Incision	Bend at Steep Slope	4	Forest	Shrubs Small Trees	N	48	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	33-ES	RB	Stage I Incision	Bend at Steep Slope	5	Forest	Shrubs Small Trees	N	27	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	34-ES	RB	Stage I Incision	Bend at Steep Slope	6	Forest	Shrubs Small Trees	N	78	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	35-ES	RB	Stage II Widening	Bend at Steep Slope	6	Forest	Shrubs Small Trees	N	50	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	36-ES	RB	Stage II Widening	Bend at Steep Slope	6	Forest	Shrubs Small Trees	N	31	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	37-ES	LB	Stage II Widening	Bend at Steep Slope	5	Forest	Forest	N	542	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	40-ES	RB	Stage I Incision	Bend at Steep Slope	6	Forest	Shrubs Small Trees	N	78	Moderate
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	42-ES	LB	Stage I Incision	Bend at Steep Slope	6	Shrubs Small Trees	Shrubs Small Trees	N	181	Minor

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BANK	CHANNEL CONDITION	CAUSE	AVG. EXPOSED BANK HEIGHT (FT)	LAND USE (LEFT)	LAND USE (RIGHT)	THREAT TO INFRA-STRUCTURE	LENGTH (FT)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	43-ES	RB	Stage I Incision	Bend at Steep Slope	4	Shrubs Small Trees	Shrubs Small Trees	N	88	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	44-ES	LB	Stage I Incision	Bend at Steep Slope	4	Forest	Shrubs Small Trees	N	74	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	45-ES	RB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	55	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	46-ES	LB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	34	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	47-ES	RB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	62	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	48-ES	LB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	612	Moderate
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	50-ES	RB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	105	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	51-ES	RB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	38	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	52-ES	LB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	53	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	53-ES	LB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	65	Minor
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	01-ES	LB	Stage I Incision	Bend at Steep Slope	6	Forest	Forest	N	100	Low Severity
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	02-ES	LB	Stage II Widening	Bend at Steep Slope	9	Shrubs Small Trees	Forest	N	69	Severe
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	03-ES	RB	Stage I Incision	Bend at Steep Slope	6	Forest	Forest	N	107	Minor
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	07-ES	RB	Stage I Incision	Bend at Steep Slope	2	Forest	Forest	N	55	Minor
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	11-ES	RB	Stage I Incision	Bend at Steep Slope	5	Shrubs Small Trees	Pasture	N	70	Low Severity
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	13-ES	LB	Stage I Incision	Bend at Steep Slope	2	Shrubs Small Trees	Shrubs Small Trees	N	723	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039A1	21-ES	LB	Stage I Incision	Bend at Steep Slope	5	Pasture	Pasture	N	204	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039B1	54-ES	RB	Stage II Widening	Land Use Change	3	Forest	Other	N	53	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039B1	54-ES	RB	Stage II Widening	Land Use Change	3	Forest	Other	N	32	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039B1	54-ES	RB	Stage II Widening	Land Use Change	3	Forest	Other	N	37	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039B1	54-ES	RB	Stage II Widening	Land Use Change	3	Forest	Other	N	41	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	22-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	51	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	23-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	77	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	24-ES	LB	Stage II Widening	Land Use Change	4	Forest	Forest	N	53	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	25-ES	RB	Stage II Widening	Land Use Change	1	Forest	Shrubs Small Trees	N	28	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	26-ES	RB	Stage II Widening	Land Use Change	3	Forest	Shrubs Small Trees	N	16	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	27-ES	LB	Stage II Widening	Land Use Change	2	Forest	Shrubs Small Trees	N	88	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	28-ES	RB	Stage II Widening	Land Use Change	2	Shrubs Small Trees	Shrubs Small Trees	N	36	Minor

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BANK	CHANNEL CONDITION	CAUSE	AVG. EXPOSED BANK HEIGHT (FT)	LAND USE (LEFT)	LAND USE (RIGHT)	THREAT TO INFRA-STRUCTURE	LENGTH (FT)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	27-ES	LB	Stage II Widening	Land Use Change	3	Forest	Shrubs Small Trees	N	37	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	29-ES	RB	Stage I Incision	Land Use Change	3	Shrubs Small Trees	Shrubs Small Trees	N	29	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	32-ES	RB	Stage II Widening	Land Use Change	2	Other	Other	N	18	Moderate
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	35-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	109	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	36-ES	RB	Stage II Widening	Land Use Change	2	Forest	Forest	N	67	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	36-ES	RB	Stage II Widening	Land Use Change	2	Forest	Forest	N	7	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	36-ES	RB	Stage II Widening	Land Use Change	2	Forest	Forest	N	65	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	37-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	80	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	33-ES	LB	Stage II Widening	Land Use Change	2	Other	Other	N	31	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	01-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	36	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	02-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	27	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	03-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	63	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	04-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	40	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	07-ES	LB	Stage I Incision	Land Use Change	3	Shrubs Small Trees	Forest	N	135	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	08-ES	RB	Stage I Incision	Land Use Change	3	Shrubs Small Trees	Forest	N	48	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	08-ES	RB	Stage I Incision	Land Use Change	3	Shrubs Small Trees	Forest	N	23	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	07-ES	LB	Stage I Incision	Land Use Change	3	Forest	Forest	N	105	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	07-ES	LB	Stage I Incision	Land Use Change	3	Forest	Forest	N	51	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	08-ES	RB	Stage I Incision	Land Use Change	3	Forest	Forest	N	51	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	039A1	38-ES	RB	Stage II Widening	Land Use Change	3	Forest	Shrubs Small Trees	N	52	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	039A1	40-ES	LB	Stage II Widening	Land Use Change	3	Forest	Shrubs Small Trees	N	112	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	14-ES	RB	Stage II Widening	Land Use Change	2	Forest	Shrubs Small Trees	N	54	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	16-ES	RB	Stage II Widening	Land Use Change	2	Forest	Shrubs Small Trees	N	128	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	20-ES	LB	Stage II Widening	Land Use Change	4	Forest	Forest	N	40	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	21-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	45	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	22-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	134	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	23-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	22	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	24-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	31	Minor

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BANK	CHANNEL CONDITION	CAUSE	AVG. EXPOSED BANK HEIGHT (FT)	LAND USE (LEFT)	LAND USE (RIGHT)	THREAT TO INFRA-STRUCTURE	LENGTH (FT)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	25-ES	RB	Stage II Widening	Land Use Change	2	Forest	Forest	N	48	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	24-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	29	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	26-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	72	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	27-ES	RB	Stage II Widening	Land Use Change	2	Forest	Forest	N	102	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	28-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	33	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	29-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	46	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	30-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	22	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	31-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	39	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	36-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	106	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	37-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	71	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	36-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	44	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	39-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	53	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	02-ES	RB	Stage I Incision	Pipe Outfall	5	Lawn	Shrubs Small Trees	N	44	Severe
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	03-ES	LB	Stage I Incision	Pipe Outfall	5	Lawn	Shrubs Small Trees	N	29	Severe
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	07-ES	LB	Stage I Incision	Land Use Change	5	Forest	Lawn	N	25	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	08-ES	LB	Stage I Incision	Land Use Change	3	Forest	Lawn	N	75	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	09-ES	RB	Stage I Incision	Land Use Change	6	Forest	Lawn	N	23	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	12-ES	RB	Stage I Incision	Land Use Change	4	Forest	Lawn	N	166	Moderate
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	13-ES	LB	Stage I Incision	Land Use Change	4	Forest	Lawn	N	107	Moderate
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	16-ES	RB	Stage I Incision	Land Use Change	3	Shrubs Small Trees	Forest	N	23	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	17-ES	LB	Stage I Incision	Land Use Change	3	Shrubs Small Trees	Forest	N	19	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	16-ES	RB	Stage I Incision	Land Use Change	3	Shrubs Small Trees	Forest	N	17	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	17-ES	LB	Stage I Incision	Land Use Change	3	Shrubs Small Trees	Forest	N	36	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	18-ES	LB	Stage I Incision	Land Use Change	4	Shrubs Small Trees	Forest	N	60	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	18-ES	LB	Stage I Incision	Land Use Change	4	Shrubs Small Trees	Forest	N	72	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	16-ES	RB	Stage I Incision	Land Use Change	3	Shrubs Small Trees	Forest	N	81	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	20-ES	RB	Stage I Incision	Land Use Change	1	Shrubs Small Trees	Forest	N	39	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	20-ES	RB	Stage I Incision	Land Use Change	1	Shrubs Small Trees	Forest	N	124	Minor

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BANK	CHANNEL CONDITION	CAUSE	AVG. EXPOSED BANK HEIGHT (FT)	LAND USE (LEFT)	LAND USE (RIGHT)	THREAT TO INFRA-STRUCTURE	LENGTH (FT)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	22-ES	RB	Stage I Incision	Land Use Change	4	Shrubs Small Trees	Forest	N	20	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	18-ES	LB	Stage I Incision	Land Use Change	4	Shrubs Small Trees	Forest	N	32	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	18-ES	LB	Stage I Incision	Land Use Change	4	Shrubs Small Trees	Forest	N	34	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	03-ES	RB	Stage I Incision	Land Use Change	6	Forest	Shrubs Small Trees	N	46	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	04-ES	RB	Stage I Incision	Land Use Change	4	Forest	Shrubs Small Trees	N	52	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	06-ES	RB	Stage I Incision	Land Use Change	3	Forest	Shrubs Small Trees	N	60	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	07-ES	LB	Stage I Incision	Land Use Change	6	Forest	Shrubs Small Trees	N	24	Moderate
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	08-ES	LB	Stage I Incision	Land Use Change	5	Forest	Shrubs Small Trees	N	14	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	09-ES	LB	Stage I Incision	Land Use Change	3	Forest	Shrubs Small Trees	N	7	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	09-ES	LB	Stage I Incision	Land Use Change	3	Forest	Shrubs Small Trees	N	19	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	12-ES	RB	Stage I Incision	Land Use Change	5	Forest	Shrubs Small Trees	N	27	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	17-ES	RB	Stage I Incision	Land Use Change	2	Shrubs Small Trees	Forest	N	35	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	18-ES	LB	Stage I Incision	Land Use Change	4	Shrubs Small Trees	Forest	N	13	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	20-ES	RB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	18	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	22-ES	LB	Stage I Incision	Land Use Change	4	Other	Crop Field	N	30	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	23-ES	RB	Stage I Incision	Land Use Change	4	Other	Crop Field	N	25	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C2	02-ES	RB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	134	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C2	03-ES	LB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	72	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C2	04-ES	LB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	21	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C2	05-ES	RB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	19	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	08-ES	LB	Stage I Incision	Land Use Change	10	Other	Forest	N	246	Very Severe
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	09-ES	RB	Stage I Incision	Land Use Change	8	Other	Forest	N	238	Very Severe
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	10-ES	LB	Stage I Incision	Land Use Change	6	Other	Forest	N	257	Severe
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	11-ES	RB	Stage I Incision	Land Use Change	6	Forest	Crop Field	N	257	Severe
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	13-ES	LB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	106	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	14-ES	RB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	59	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	14-ES	RB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	24	Moderate

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BANK	CHANNEL CONDITION	CAUSE	AVG. EXPOSED BANK HEIGHT (FT)	LAND USE (LEFT)	LAND USE (RIGHT)	THREAT TO INFRA-STRUCTURE	LENGTH (FT)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	13-ES	LB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	71	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	14-ES	RB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	53	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	14-ES	RB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	36	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	17-ES	LB	Stage I Incision	Land Use Change	3	Forest	Lawn	N	57	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	18-ES	RB	Stage I Incision	Land Use Change	3	Forest	Lawn	N	59	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	19-ES	LB	Stage I Incision	Land Use Change	1	Forest	Lawn	N	36	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	21-ES	RB	Stage I Incision	Land Use Change	4	Forest	Lawn	N	55	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	24-ES	LB	Stage I Incision	Land Use Change	1	Crop Field	Crop Field	N	356	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	25-ES	RB	Stage I Incision	Land Use Change	1	Crop Field	Crop Field	N	356	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	20-ES	RB	Stage I Incision	Land Use Change	1	Forest	Lawn	N	36	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	32-ES	RB	Stage I Incision	Land Use Change	3	Crop Field	Forest	N	98	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	31-ES	LB	Stage I Incision	Land Use Change	3	Crop Field	Forest	N	206	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	30-ES	RB	Stage I Incision	Land Use Change	6	Crop Field	Forest	N	27	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	60-ES	RB	Stage I Incision	Land Use Change	1	Crop Field	Forest	N	37	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	59-ES	LB	Stage I Incision	Land Use Change	1	Crop Field	Forest	N	45	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	58-ES	RB	Stage I Incision	Land Use Change	2	Crop Field	Forest	N	106	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	57-ES	LB	Stage I Incision	Land Use Change	2	Crop Field	Forest	N	106	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	54-ES	LB	Stage I Incision	Land Use Change	4	Crop Field	Forest	N	148	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	55-ES	RB	Stage I Incision	Land Use Change	4	Crop Field	Forest	N	153	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	51-ES	LB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	28	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	50-ES	LB	Stage I Incision	Land Use Change	2	Forest	Crop Field	N	33	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	49-ES	RB	Stage I Incision	Land Use Change	3	Forest	Crop Field	N	60	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	45-ES	RB	Stage I Incision	Land Use Change	1	Crop Field	Crop Field	N	50	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	44-ES	LB	Stage I Incision	Land Use Change	2	Crop Field	Crop Field	N	90	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	43-ES	RB	Stage I Incision	Land Use Change	2	Crop Field	Crop Field	N	62	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	42-ES	LB	Stage I Incision	Land Use Change	3	Crop Field	Crop Field	N	81	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A3	40-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	89	Minor
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A3	41-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	28	Minor
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A3	42-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	42	Minor

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BANK	CHANNEL CONDITION	CAUSE	AVG. EXPOSED BANK HEIGHT (FT)	LAND USE (LEFT)	LAND USE (RIGHT)	THREAT TO INFRA-STRUCTURE	LENGTH (FT)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A3	43-ES	LB	Stage II Widening	Land Use Change	5	Forest	Forest	N	135	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A3	44-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	41	Minor
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A3	45-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	76	Minor
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A3	48-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	24	Minor
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A3	49-ES	RB	Stage II Widening	Land Use Change	2	Forest	Forest	N	45	Minor
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A3	50-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	48	Minor
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A2	23-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	25	Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	02-ES	RB	Stage II Widening	Below Road Crossing	4	Forest	Lawn	N	100	Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	03-ES	RB	Stage I Incision	Bend at Steep Slope	4	Shrubs Small Trees	Shrubs Small Trees	N	121	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	05-ES	LB	Stage I Incision	Land Use Change	5	Forest	Shrubs Small Trees	N	74	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	05-ES	LB	Stage I Incision	Land Use Change	5	Forest	Shrubs Small Trees	N	29	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	05-ES	LB	Stage I Incision	Land Use Change	5	Forest	Shrubs Small Trees	N	29	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	05-ES	LB	Stage I Incision	Land Use Change	5	Forest	Shrubs Small Trees	N	48	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	05-ES	LB	Stage I Incision	Land Use Change	5	Forest	Shrubs Small Trees	N	48	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	05-ES	LB	Stage I Incision	Land Use Change	5	Forest	Shrubs Small Trees	N	53	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	09-ES	RB	Stage I Incision	Bend at Steep Slope	8	Forest	Forest	N	109	Minor
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	10-ES	LB	Stage II Widening	Bend at Steep Slope	8	Forest	Forest	N	128	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	11-ES	LB	Stage II Widening	Bend at Steep Slope	6	Forest	Forest	N	114	Minor
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	12-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	52	Minor
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	16-ES	RB	Stage II Widening	Bend at Steep Slope	5	Forest	Forest	N	139	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	17-ES	LB	Stage I Incision	Bend at Steep Slope	4	Forest	Forest	N	138	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	25-ES	LB	Stage III Deposition	Livestock	3	Pasture	Pasture	N	1218	Severe
Liberty Reservoir	Cliffs Branch	S	10/30/2014	031B2	33-ES	LB	Stage I Incision	Land Use Change	6	Forest	Forest	N	508	Minor
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B2	39-ES	RB	Stage II Widening	Land Use Change	4	Pasture	Pasture	N	52	Minor
Liberty Reservoir	Cliffs Branch	S	10/30/2014	031B3	12-ES	LB	Stage II Widening	Pipe Outfall	5	Paved	Crop Field	Y	41	Minor
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031B3	03-ES	LB	Stage II Widening	Livestock	4	Pasture	Forest	N	192	Moderate
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031A3	51-ES	RB	Stage II Widening	Livestock	5	Pasture	Forest	N	46	Minor
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031B3	05-ES	RB	Stage II Widening	Bend at Steep Slope	6	Forest	Forest	N	62	Minor

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BANK	CHANNEL CONDITION	CAUSE	AVG. EXPOSED BANK HEIGHT (FT)	LAND USE (LEFT)	LAND USE (RIGHT)	THREAT TO INFRA-STRUCTURE	LENGTH (FT)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031B3	06-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	154	Low Severity
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031B3	08-ES	RB	Stage I Incision	Bend at Steep Slope	6	Forest	Forest	N	30	Minor
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031B3	10-ES	LB	Stage I Incision	Land Use Change	3	Forest	Shrubs Small Trees	N	688	Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	047C1	02-ES	LB	Stage II Widening	Other	7	Forest	Forest	N	17	Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	047C1	03-ES	RB	Stage II Widening	Bend at Steep Slope	3	Forest	Forest	N	54	Low Severity
Liberty Reservoir	Keyser Run	S	10/2/2014	047C1	04-ES	RB	Stage II Widening	Other	6	Forest	Forest	N	83	Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	047C1	10-ES	RB	Stage II Widening	Other	3	Lawn	Lawn	N	101	Low Severity
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	12-ES	LB	Stage II Widening	Land Use Change	5	Forest	Lawn	N	86	Moderate
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	13-ES	LB	Stage I Incision	Land Use Change	2	Forest	Forest	N	81	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048a1	02-ES	LB	Stage I Incision	Land Use Change	3	Forest	Pasture	N	91	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	06-ES	LB	Stage I Incision	Below Channelization	3	Lawn	Lawn	N	54	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	07-ES	RB	Stage I Incision	Below Channelization	3	Lawn	Lawn	N	100	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	08-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	76	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	09-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	46	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	09-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	70	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	09-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	121	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	09-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	221	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	09-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	26	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	10-ES	LB	Stage II Widening	Land Use Change	4	Forest	Forest	N	137	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	10-ES	LB	Stage II Widening	Land Use Change	4	Forest	Forest	N	48	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	10-ES	LB	Stage II Widening	Land Use Change	4	Forest	Forest	N	40	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	14-ES	LB	Stage II Widening	Land Use Change	6	Forest	Forest	N	36	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	15-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	47	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	17-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	107	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	18-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	62	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	19-ES	RB	Stage II Widening	Land Use Change	2	Forest	Forest	N	68	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	20-ES	LB	Stage II Widening	Land Use Change	6	Forest	Forest	N	33	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	21-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	52	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	22-ES	LB	Stage II Widening	Bend at Steep Slope	2	Forest	Lawn	N	22	Minor

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	**SUBWATERSHED**	**SWAP AREA**	**DATE**	**MAP**	**SITE**	**BANK**	**CHANNEL CONDITION**	**CAUSE**	**AVG. EXPOSED BANK HEIGHT (FT)**	**LAND USE (LEFT)**	**LAND USE (RIGHT)**	**THREAT TO INFRA-STRUCTURE**	**LENGTH (FT)**	**SEVERITY**
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	22-ES	LB	Stage I Incision	Land Use Change	2	Forest	Lawn	N	42	Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	23-ES	RB	Stage I Incision	Land Use Change	4	Shrubs Small Trees	Forest	N	36	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	24-ES	RB	Stage I Incision	Land Use Change	4	Forest	Forest	N	70	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	24-ES	RB	Stage I Incision	Land Use Change	4	Forest	Forest	N	37	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	25-ES	LB	Stage I Incision	Land Use Change	6	Forest	Forest	N	47	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	24-ES	RB	Stage I Incision	Land Use Change	4	Forest	Forest	N	47	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	29-ES	LB	Stage I Incision	Land Use Change	3	Forest	Forest	N	131	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	29-ES	LB	Stage I Incision	Land Use Change	3	Forest	Forest	N	141	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	30-ES	RB	Stage I Incision	Land Use Change	4	Forest	Forest	N	42	Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	30-ES	RB	Stage I Incision	Land Use Change	4	Forest	Forest	N	65	Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048b2	32-ES	LB	Stage I Incision	Land Use Change	6	Forest	Forest	N	140	Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048a2	29-ES	RB	Stage I Incision	Land Use Change	4	Forest	Forest	N	50	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048a2	31-ES	LB	Stage I Incision	Land Use Change	4	Forest	Forest	N	70	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048a2	37-ES	LB	Stage I Incision	Land Use Change	5	Crop Field	Crop Field	N	43	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048a2	40-ES	RB	Stage I Incision	Land Use Change	4	Pasture	Pasture	N	32	Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048a2	41-ES	LB	Stage I Incision	Land Use Change	4	Pasture	Pasture	N	21	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048a2	41-ES	LB	Stage I Incision	Land Use Change	4	Pasture	Pasture	N	41	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048a2	41-ES	LB	Stage I Incision	Land Use Change	4	Pasture	Pasture	N	69	Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048a2	42-ES	RB	Stage I Incision	Land Use Change	5	Pasture	Pasture	N	54	Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	048a2	20-ES	LB	Stage I Incision	Land Use Change	3	Forest	Lawn	N	341	Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	048a2	21-ES	RB	Stage I Incision	Land Use Change	5	Forest	Lawn	N	215	Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	048a2	22-ES	RB	Stage I Incision	Land Use Change	4	Forest	Lawn	N	114	Low Severity
Liberty Reservoir	Keyser Run	S	10/2/2014	048a2	26-ES	LB	Stage I Incision	Land Use Change	4	Forest	Lawn	N	69	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	45-ES	RB	Stage II Widening	Pipe Outfall	3	Multiflora	Multiflora	N	26	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	63-ES	LB	Stage II Widening	Land Use Change	4	Forest	Forest	N	35	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	47-ES	RB	Stage II Widening	Bend at Steep Slope	4	Multiflora	Multiflora	N	46	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	49-ES	LB	Stage II Widening	Land Use Change	3	Forest	Lawn	N	61	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	52-ES	RB	Stage II Widening	Land Use Change	7	Forest	Lawn	N	58	Moderate
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	53-ES	LB	Stage II Widening	Land Use Change	7	Forest	Lawn	N	83	Moderate

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BANK	CHANNEL CONDITION	CAUSE	AVG. EXPOSED BANK HEIGHT (FT)	LAND USE (LEFT)	LAND USE (RIGHT)	THREAT TO INFRA-STRUCTURE	LENGTH (FT)	SEVERITY
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	54-ES	RB	Stage II Widening	Land Use Change	6	Forest	Lawn	N	51	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	55-ES	LB	Stage II Widening	Land Use Change	5	Forest	Lawn	N	103	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	56-ES	RB	Stage II Widening	Land Use Change	4	Forest	Lawn	N	42	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	58-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	31	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	59-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	109	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	61-ES	LB	Stage II Widening	Land Use Change	9	Forest	Forest	N	110	Moderate
Liberty Reservoir	Keyser Run	S	10/9/2014	048a2	61-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	142	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	01-ES	LB	Stage I Incision	Land Use Change	4	Forest	Forest	N	139	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	02-ES	RB	Stage I Incision	Land Use Change	4	Forest	Forest	N	128	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	03-ES	LB	Stage I Incision	Land Use Change	5	Forest	Forest	N	39	Moderate
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	04-ES	RB	Stage I Incision	Land Use Change	5	Forest	Forest	N	28	Moderate
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	05-ES	LB	Stage I Incision	Land Use Change	2	Forest	Forest	N	155	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	06-ES	RB	Stage I Incision	Land Use Change	2	Forest	Forest	N	155	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	07-ES	RB	Stage I Incision	Land Use Change	6	Forest	Forest	N	112	Severe
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	08-ES	RB	Stage I Incision	Land Use Change	6	Forest	Forest	N	120	Severe
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	10-ES	RB	Stage I Incision	Land Use Change	5	Forest	Forest	N	121	Moderate
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	09-ES	LB	Stage I Incision	Land Use Change	5	Forest	Forest	N	201	Moderate
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	11-ES	RB	Stage I Incision	Land Use Change	3	Forest	Forest	N	50	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	12-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	15	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	13-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	26	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	16-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	99	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	17-ES	RB	Stage II Widening	Land Use Change	2	Forest	Forest	N	63	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	18-ES	RB	Stage I Incision	Land Use Change	3	Forest	Forest	N	151	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	20-ES	LB	Stage I Incision	Land Use Change	3	Forest	Forest	N	33	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	21-ES	RB	Stage I Incision	Land Use Change	3	Forest	Forest	N	37	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	22-ES	LB	Stage I Incision	Land Use Change	3	Forest	Forest	N	8	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	23-ES	RB	Stage I Incision	Land Use Change	3	Forest	Forest	N	40	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	22-ES	LB	Stage I Incision	Land Use Change	3	Forest	Forest	N	39	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	25-ES	RB	Stage I Incision	Land Use Change	2	Forest	Forest	N	69	Minor

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BANK	CHANNEL CONDITION	CAUSE	AVG. EXPOSED BANK HEIGHT (FT)	LAND USE (LEFT)	LAND USE (RIGHT)	THREAT TO INFRA-STRUCTURE	LENGTH (FT)	SEVERITY
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	26-ES	RB	Stage I Incision	Land Use Change	2	Forest	Forest	N	18	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	29-ES	LB	Stage II Widening	Land Use Change	4	Forest	Forest	N	50	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	31-ES	LB	Stage I Incision	Land Use Change	3	Forest	Forest	N	28	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	34-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	22	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	36-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	27	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	36-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	29	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	16-ES	LB	Stage I Incision	Land Use Change	3	Forest	Forest	N	117	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	23-ES	RB	Stage II Widening	Land Use Change	5	Forest	Pasture	N	341	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	27-ES	LB	Stage II Widening	Land Use Change	3	Forest	Forest	N	97	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	28-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	54	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	29-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	75	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	30-ES	LB	Stage II Widening	Land Use Change	4	Forest	Forest	N	54	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	31-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	22	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	32-ES	LB	Stage II Widening	Land Use Change	2	Forest	Forest	N	44	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	33-ES	RB	Stage II Widening	Land Use Change	2	Forest	Forest	N	45	Minor
Liberty Reservoir	Keyser Run	S	10/09/2014	048A2	64-ES	LB	Stage II Widening	Land Use Change	6	Forest	Forest	N	37	Low Severity
Liberty Reservoir	Keyser Run	S	10/09/2014	048A2	65-ES	RB	Stage II Widening	Land Use Change	5	Forest	Forest	N	208	Low Severity
Liberty Reservoir	Keyser Run	S	10/09/2014	048A2	64-ES	LB	Stage II Widening	Land Use Change	5	Forest	Forest	N	22	Low Severity
Liberty Reservoir	Keyser Run	S	10/09/2014	048A2	64-ES	LB	Stage II Widening	Land Use Change	4	Forest	Forest	N	47	Low Severity
Liberty Reservoir	Keyser Run	S	10/09/2014	048A2	65-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	19	Low Severity
Liberty Reservoir	Keyser Run	S	10/09/2014	048A2	64-ES	LB	Stage II Widening	Land Use Change	4	Forest	Forest	N	160	Low Severity
Liberty Reservoir	Keyser Run	S	10/09/2014	048A2	65-ES	RB	Stage II Widening	Land Use Change	4	Forest	Forest	N	97	Low Severity
Liberty Reservoir	Norris Run	S	9/26/2014	048a2	06-ES	RB	Stage II Widening	Other	5	Forest	Forest	N	124	Minor
Liberty Reservoir	Norris Run	S	10/10/2014	048A3	01-ES	LB	Stage II Widening	Land Use Change	6	Forest	Shrubs Small Trees	N	62	Minor
Liberty Reservoir	Norris Run	S	10/10/2014	048A3	03-ES	RB	Stage II Widening	Livestock	5	Forest	Forest	N	104	Low Severity
Liberty Reservoir	Norris Run	S	10/10/2014	048A2	13-ES	RB	Stage II Widening	Land Use Change	3	Forest	Forest	N	75	Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	08-ES	LB	Stage I Incision	Bend at Steep Slope	5	Multiflora	Multiflora	N	65	Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	09-ES	RB	Stage I Incision	Bend at Steep Slope	4	Multiflora	Multiflora	N	66	Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	12-ES	LB	Stage I Incision	Bend at Steep Slope	8	Multiflora	Shrubs Small Trees	N	65	Minor

Liberty Reservoir SCA Data: Erosion Sites														
WATERSHED	**SUBWATERSHED**	**SWAP AREA**	**DATE**	**MAP**	**SITE**	**BANK**	**CHANNEL CONDITION**	**CAUSE**	**AVG. EXPOSED BANK HEIGHT (FT)**	**LAND USE (LEFT)**	**LAND USE (RIGHT)**	**THREAT TO INFRA-STRUCTURE**	**LENGTH (FT)**	**SEVERITY**
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	30-ES	RB	Stage II Widening	Bend at Steep Slope	6	Forest	Lawn	N	27	Minor
Liberty Reservoir	Norris Run	S	10/3/2014	048B2	15-ES	LB	Stage II Widening	Bend at Steep Slope	6	Forest	Forest	N	42	Minor
Liberty Reservoir	Norris Run	S	10/10/14	048B2	18-ES	LB	Stage I Incision	Land Use Change	6	Shrubs Small Trees	Forest	N	63	Low Severity

Liberty Reservoir SCA Data: Inadequate Buffers																
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BUFFER INADEQUATE ON	STREAM UNSHADED ON	BUFFER WIDTH LEFT (FT)	BUFFER WIDTH RIGHT (FT)	BUFFER LENGTH (FT)	LAND USE LEFT	LAND USE RIGHT	BUFFER RECENTLY ESTABLISH-ED	LIVESTOCK PRESENT?	IF YES, TYPE	SEVERITY
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	13-IB	Both	Both	0	0	59	Other	Other	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	15-IB	Both	Both	0	0	166	Shrubs Small Trees	Crop field	N	N		Severe
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	17-IB	Both	Both	0	0	348	Crop field	Crop field	N	N		Severe
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	19-IB	Right	Both	>50	0	270	Forest	Crop field	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	23-IB	Right	Both	>50	>50	264	Forest	Shrubs Small Trees	Y	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	31-IB	Right	Both	>50	10	734	Forest	Shrubs Small Trees	Y	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	41-IB	Right	Both	>50	>50	100	Shrubs Small Trees	Shrubs Small Trees	Y	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	09-IB	Right	Both	20	10	1191	Pasture	Pasture	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039A1	19-IB	Both	Both	0	0	142	Pasture	Pasture	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039B1	55-IB	Right	Both	>50	>50	153	Forest	Other	N	N		Moderate
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	31-IB	Both	Both	0	0	218	Other	Other	N	N		Severe
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	17-IB	Right	Neither	>50	10	693	Shrubs Small Trees	Pasture	N	N		Moderate
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	18-IB	Right	Neither	15	10	333	Pasture	Pasture	N	N		Moderate
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	33-IB	Right	Neither	>50	10	413	Forest	Crop field	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	35-IB	Left	Neither	10	>50	38	Pasture	Shrubs Small Trees	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	01-IB	Both	Left	10	20	231	Crop field	Shrubs Small Trees	Y	N		Moderate
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	05-IB	Right	Neither	>50	20	439	Forest	Other	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	10-IB	Both	Both	10	10	523	Multiflora Rose	Multiflora Rose	Y	N		Moderate
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	14-IB	Left	Neither	30	>50	567	Shrubs Small Trees	Forest	Y	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	21-IB	Both	Neither	30	20	188	Shrubs Small Trees	Crop field	Y	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	05-IB	Right	Right	>50	10	288	Forest	Shrubs Small Trees	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	19-IB	Left	Neither	20	>50	736	Other	Forest	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	21-IB	Both	Neither	20	20	180	Other	Crop field	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C2	01-IB	Right	Neither	>50	30	899	Forest	Crop field	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	12-IB	Right	Right	>50	20	513	Forest	Crop field	N	N		Low Severity

Liberty Reservoir SCA Data: Inadequate Buffers																
WATERSHED	**SUBWATERSHED**	**SWAP AREA**	**DATE**	**MAP**	**SITE**	**BUFFER INADEQUATE ON**	**STREAM UNSHADED ON**	**BUFFER WIDTH LEFT (FT)**	**BUFFER WIDTH RIGHT (FT)**	**BUFFER LENGTH (FT)**	**LAND USE LEFT**	**LAND USE RIGHT**	**BUFFER RECENTLY ESTABLISH-ED**	**LIVESTOCK PRESENT?**	**IF YES, TYPE**	**SEVERITY**
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	15-IB	Right	Right	>50	0	429	Forest	Lawn	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	07-IB	Left	Left	20	>50	234	Other	Forest	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	22-IB	Both	Both	0	0	767	Crop field	Crop field	N	N		Severe
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	33-IB	Right	Neither	>50	30	107	Crop field	Crop field	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	52-IB	Left	Neither	30	>50	876	Crop field	Forest	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	46-IB	Right	Right	>50	0	372	Forest	Crop field	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/27/2014	031A3	47-IB	Both	Both	>50	>50	191	Shrubs Small Trees	Shrubs Small Trees	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/21/2014	031C3	01-IB	Both	Neither	10	10	1170	Shrubs Small Trees	Shrubs Small Trees	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/21/2014	031C3	24-IB	Right	Neither	>50	20	354	Forest	Crop field	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B1	03-IB	Both	Both	10	10	565	Crop field	Crop field	N	N		Moderate
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B1	06-IB	Both	Both	10	10	240	Lawn	Lawn	N	N		Moderate
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B1	08-IB	Right	Neither	>50	20	257	Forest	Crop field	N	N		Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B1	09-IB	Both	Right	0	0	1243	Pasture	Pasture	N	Y		Moderate
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	04-IB	Right	Right	>50	5	52	Forest	Pasture	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	06-IB	Both	Right	>50	5	946	Shrubs Small Trees	Pasture	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	14-IB	Both	Both	10	10	1025	Crop field	Crop field	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	20-IB	Left	Left	25	>50	577	Lawn	Shrubs Small Trees	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	23-IB	Left	Left	0	10	312	Lawn	Shrubs Small Trees	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	24-IB	Both	Both	0	0	2146	Pasture	Pasture	N	Y		Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	26-IB	Both	Both	0	0	1161	Pasture	Pasture	N	Y		Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	30-IB	Left	Left	10	>50	310	Crop field	Forest	N	N		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/30/2014	031B2	34-IB	Both	Neither	25	40	420	Shrubs Small Trees	Forest	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B2	36-IB	Left	Neither	10	>50	400	Pasture	Forest	N	Y	Horses	Minor
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B2	38-IB	Both	Both	0	0	251	Pasture	Lawn	N	Y	Horses	Minor
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B2	41-IB	Both	Both	15	15	640	Pasture	Crop field	N	Y	Horses	Minor
Liberty Reservoir	Cliffs Branch	S	10/30/2014	031B3	14-IB	Left	Left	15	>50	92	Lawn	Forest	N	N		Minor

Liberty Reservoir SCA Data: Inadequate Buffers																
WATERSHED	**SUBWATERSHED**	**SWAP AREA**	**DATE**	**MAP**	**SITE**	**BUFFER INADEQUATE ON**	**STREAM UNSHADED ON**	**BUFFER WIDTH LEFT (FT)**	**BUFFER WIDTH RIGHT (FT)**	**BUFFER LENGTH (FT)**	**LAND USE LEFT**	**LAND USE RIGHT**	**BUFFER RECENTLY ESTABLISH-ED**	**LIVESTOCK PRESENT?**	**IF YES, TYPE**	**SEVERITY**
Liberty Reservoir	Cliffs Branch	S	10/30/2014	031B3	13-IB	Both	Both	0	15	44	Paved	Crop field	N	N		Minor
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031B3	01-IB	Left	Left	10	>50	1014	Pasture	Forest	N	N		Moderate
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031B3	09-IB	Right	Neither	>50	20	583	Forest	Shrubs Small Trees	N	N		Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	047C1	08-IB	Right	Right	>50	0	569	Forest	Lawn	N	N		Moderate
Liberty Reservoir	Keyser Run	S	10/2/2014	047C1	09-IB	Both	Right	15	0	536	Lawn	Lawn	N	Y	Horses	Moderate
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	08-IB	Right	Right	>50	0	1909	Forest	Lawn	N	N		Moderate
Liberty Reservoir	Keyser Run	S	10/6/2014	048A1	01-IB	Right	Neither	10	20	193	Pasture	Pasture	N	N		Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	05-IB	Both	Neither	25	25	216	Lawn	Lawn	N	N		Minor
Liberty Reservoir	Keyser Run	S	10/1/2014	039B1	08-IB	Right	Right	>50	25	873	Forest	Pasture	N	N		Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048B2	21-IB	Both	Both	0	0	53	Lawn	Lawn	N	N		Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048A2	30-IB	Right	Right	>50	20	442	Crop field	Crop field	N	N		Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048A2	33-IB	Both	Both	>50	15	1417	Crop field	Crop field	N	N		Moderate
Liberty Reservoir	Keyser Run	S	10/6/2014	048A2	39-IB	Both	Both	0	0	845	Crop field	Crop field	N	N		Severe
Liberty Reservoir	Keyser Run	S	10/9/2014	048A2	50-IB	Right	Neither	>50	10	833	Forest	Lawn	N	N		Moderate
Liberty Reservoir	Keyser Run	S	10/9/2014	048A2	60-IB	Left	Right	10	10	328	Lawn	Forest	N	N		Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	32-IB	Right	Neither	>50	30	177	Forest	Pasture	N	N		Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	35-IB	Right	Right	>50	0	748	Forest	Pasture	N	N		Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	24-IB	Both	Right	0	0	146	Other	Lawn	N	N		Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	26-IB	Right	Right	>50	30	477	Forest	Lawn	N	N		Minor
Liberty Reservoir	Norris Run	S	9/23/2014	048A2	01-IB	Right	Neither	>50	20	79	Forest	Shrubs Small Trees	N	N		Low Severity
Liberty Reservoir	Norris Run	S	9/26/2014	048A2	02-IB	Right	Neither	>50	40	145	Shrubs Small Trees	Shrubs Small Trees	N	N		Minor
Liberty Reservoir	Norris Run	S	9/26/2014	048A2	03-IB	Left	Left	20	>50	97	Shrubs Small Trees	Shrubs Small Trees	N	N		Minor
Liberty Reservoir	Norris Run	S	9/26/2014	048A2	04-IB	Left	Left	30	>50	97	Crop field	Crop field	N	N		Low Severity
Liberty Reservoir	Norris Run	S	9/26/2014	048A2	05-IB	Right	Right	>50	5	174	Shrubs Small Trees	Crop field	N	N		Moderate
Liberty Reservoir	Norris Run	S	9/26/2014	048A2	07-IB	Right	Neither	>50	40	173	Shrubs Small Trees	Shrubs Small Trees	N	N		Minor
Liberty Reservoir	Norris Run	S	9/26/2014	048A2	09-IB	Right	Right	>50	0	93	Shrubs Small Trees	Lawn	N	N		Moderate

Liberty Reservoir SCA Data: Inadequate Buffers																
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BUFFER INADEQUATE ON	STREAM UNSHADED ON	BUFFER WIDTH LEFT (FT)	BUFFER WIDTH RIGHT (FT)	BUFFER LENGTH (FT)	LAND USE LEFT	LAND USE RIGHT	BUFFER RECENTLY ESTABLISH-ED	LIVESTOCK PRESENT?	IF YES, TYPE	SEVERITY
Liberty Reservoir	Norris Run	S	9/26/2014	048A2	11-IB	Left	Left	0	>50	199	Shrubs Small Trees	Shrubs Small Trees	N	N		Severe
Liberty Reservoir	Norris Run	S	10/10/2014	048A2	15-IB	Both	Neither	10	10	76	Crop field	Pasture	N	N		Minor
Liberty Reservoir	Norris Run	S	10/10/2014	048A3	02-IB	Right	Neither	0	>50	141	Shrubs Small Trees	Pasture	N	N		Minor
Liberty Reservoir	Norris Run	S	10/10/2014	048B2	19-IB	Right	Neither	>50	0	122	Shrubs Small Trees	Crop field	N	N		Minor
Liberty Reservoir	Norris Run	S	10/10/2014	048A2	14-IB	Right	Right	10	>50	202	Forest	Lawn	N	N		Minor
Liberty Reservoir	Norris Run	S	10/10/2014	048A2	12-IB	Both	Both	0	0	69	Lawn	Lawn	N	N		Moderate
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	02-IB	Right	Both	10	15	156	Shrubs Small Trees	Multiflora Rose	N	N		Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	03-IB	Right	Both	10	4	104	Lawn	Shrubs Small Trees	N	N		Low Severity
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	04-IB	Both	Neither	5	5	78	Crop field	Crop field	N	N		Low Severity
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	31-IB	Both	Neither	10	10	56	Lawn	Lawn	N	N		Minor
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	38-IB	Left	Left	10	>50	276	Lawn	Forest	N	N		Minor
Liberty Reservoir	Norris Run	S	10/3/2014	048B2	14-IB	Left	Left	30	30	19	Lawn	Shrubs Small Trees	N	N		Minor
Liberty Reservoir	Norris Run	S	10/10/2014	048B2	17-IB	Left	Left	0	>50	139	Lawn	Forest	N	N		Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	13-IB	Right	Right	>50	15	963	Forest	Other	N	N		Moderate

Liberty Reservoir SCA Data: Trash Dumping													
WATERSHED	**SUBWATERSHED**	**SWAP AREA**	**DATE**	**MAP**	**SITE**	**TYPE OF TRASH**	**AMOUNT PICKUP TRUCK LOADS**	**OTHER MEASURE**	**TRASH CONFINED TO**	**SITE FOR VOLUNTEERS**	**LAND OWNERSHIP**	**NAME IF PUBLIC**	**SEVERITY**
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B1	07-TD	Yard Waste	4		Single Site	N	Private		Moderate
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	10-TD	Other	1		Single Site	N	Private		Minor
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	21-TD	Other	3		Single Site	N	Private		Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	02-TD	Other	10		Large Area	N	Private		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	02-TD	Other	10		Large Area	N	Private		Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C2	06-TD	Other	25		Large Area	N	Private		Severe
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	27-TD	Construction	4		Single Site	N	Private		Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	28-TD	Tires	1		Single Site	N	Private		Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B1	11-TD	Tires	1		Single Site	Y	Private		Low Severity
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	05-TD	Yard Waste	5		Single Site	N	Private		Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	06-TD	Yard Waste	5		Single Site	N	Private		Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	048A2	23-TD	Construction	2		Large Area	Y	Public	Permanent Easement	Low Severity
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	03-TD	Yard Waste	4		Single Site	N	Private		Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	04-TD	Construction	1		Single Site	N	Private		Low Severity
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	08-TD	Residential	1		Single Site	N	Public	Public	Low Severity

Liberty Reservoir SCA Data: Fish Barriers											
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BLOCKAGE TYPE	BARRIER TYPE	BLOCKAGE BECAUSE	WATER DROP (IN)	WATER DEPTH (IN)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	04-FB	Total	Natural Falls	Too high	12	6	Minor
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	05-FB	Total	Natural Falls	Too high	12	4	Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039B1	09-FB	Total	Other	Too high	36	8	Moderate
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	01-FB	Total	Road Crossing	Too high	24	2	Moderate
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	07-FB	Partial	Debris Dam	Too shallow	8	24	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	32-FB	Partial	Debris Dam	Too high	0	0	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	39-FB	Total	Debris Dam	Too high	24	8	Moderate
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B1	01-FB	Total	Natural Falls	Too high	6	6	Minor
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B1	02-FB	Total	Natural Falls	Too high	6	6	Minor
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B1	05-FB	Total	Dam	Too shallow	0	1	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	09-FB	Total	Natural Falls	Too high	18	1	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	11-FB	Total	Natural Falls	Too high	18	2	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	13-FB	Total	Natural Falls	Too high	24	3	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	15-FB	Partial	Debris Dam	Too shallow	0	1	Minor
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	19-FB	Total	Road Crossing	Too high	12	4	Severe
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	32-FB	Total	Other	Too high	24	1	Moderate
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	34-FB	Total	Other	Too high	18	1	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	11-FB	Total	Road Crossing	Too high	12	3	Moderate
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	13-FB	Partial	Natural Falls	Too high	8	2	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	14-FB	Total	Natural Falls	Too high	24	12	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	15-FB	Total	Natural Falls	Too high	12	3	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	16-FB	Total	Natural Falls	Too high	12	3	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	06-FB	Temporary	Debris Dam	Too high	8	2	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	11-FB	Temporary	Debris Dam	Too high	12	2	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	16-FB	Total	Natural Falls	Too high	48	18	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	48-FB	Total	Channelized	Too shallow	4	6	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	53-FB	Total	Natural Falls	Too high	24	1	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	56-FB	Total	Natural Falls	Too high	24	2	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	29-FB	Total	Natural Falls	Too high	24	1	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031A2	15-FB	Total	Natural Falls	Too high	24	1	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031A2	19-FB	Total	Natural Falls	Too high	8	1	Minor

Liberty Reservoir SCA Data: Fish Barriers											
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BLOCKAGE TYPE	BARRIER TYPE	BLOCKAGE BECAUSE	WATER DROP (IN)	WATER DEPTH (IN)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	10/30/2014	031B3	11-FB	Total	Road Crossing	Too high	6	18	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/30/2014	031B3	35-FB	Total	Natural Falls	Too shallow	18	1	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	28-FB	Total	Road Crossing	Too high	12	3	Low Severity
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031B3	07-FB	Total	Debris Dam	Too high	18	1	Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	047C1	06-FB	Partial	Road Crossing	Too fast	12	8	Moderate
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	07-FB	Partial	Debris Dam	Too shallow	0	6	Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	10-FB	Partial	Road Crossing	Too high	66	15	Very Severe
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	14-FB	Total	Natural Falls	Too high	15	1	Low Severity
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	15-FB	Total	Natural Falls	Too high	18	3	Low Severity
Liberty Reservoir	Keyser Run	S	10/2/2014	048A2	27-FB	Total	Road Crossing	Too high	6	3	Severe
Liberty Reservoir	Keyser Run	S	10/9/2014	048A2	43-FB	Total	Road Crossing	Too high	12	7	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A2	57-FB	Total	Dam	Too high	18	12	Severe
Liberty Reservoir	Keyser Run	S	10/9/2014	048A2	62-FB	Partial	Natural Falls	Too fast	24	12	Moderate
Liberty Reservoir	Keyser Run	S	10/6/2014	048B2	26-FB	Partial	Debris Dam	Too shallow	0	6	Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048B2	27-FB	Partial	Debris Dam	Too shallow	5	3	Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048A2	34-FB	Partial	Road Crossing	Too high	6	1	Moderate
Liberty Reservoir	Keyser Run	S	10/6/2014	048A2	36-FB	Partial	Debris Dam	Too shallow	18	3	Moderate
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	15-FB	Partial	Debris Dam	Too high	4	2	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	19-FB	Total	Debris Dam	Too high	24	2	Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	27-FB	Total	Natural Falls	Too high	15	9	Moderate
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	30-FB	Total	Natural Falls	Too high	15	12	Moderate
Liberty Reservoir	Norris Run	S	9/23/2014	047C2	02-FB	Total	Road Crossing	Too high	12	12	Moderate
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	10-FB	Partial	Debris Dam	Too shallow	26	3	Low Severity
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	14-FB	Partial	Debris Dam	Too shallow	10	3	Low Severity
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	15-FB	Partial	Debris Dam	Too shallow	6	1	Low Severity
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	17-FB	Partial	Debris Dam	Too high	24	1	Severe
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	24-FB	Partial	Natural Falls	Too shallow	24	1	Minor
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	26-FB	Total	Debris Dam	Too shallow	0	0	Minor
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	27-FB	Total	Debris Dam	Too shallow	0	0	Minor
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	28-FB	Total	Natural Falls	Too high	31	5	Minor
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	29-FB	Total	Natural Falls	Too high	13	4	Minor

Liberty Reservoir SCA Data: Fish Barriers											
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	BLOCKAGE TYPE	BARRIER TYPE	BLOCKAGE BECAUSE	WATER DROP (IN)	WATER DEPTH (IN)	SEVERITY
Liberty Reservoir	Norris Run	S	10/3/2014	048A3	05-FB	Total	Channelized	Too high	1	1	Moderate
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	33-FB	Total	Debris Dam	Too high	3	1	Moderate
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	34-FB	Total	Debris Dam	Too high	30	3	Moderate
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	35-FB	Total	Debris Dam	Too shallow	0	1	Minor
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	39-FB	Total	Debris Dam	Too high	3	5	Minor
Liberty Reservoir	Norris Run	S	9/26/2014	048A2	08-FB	Total	Natural Falls	Too high	21	8	Minor
Liberty Reservoir	Norris Run	S	9/26/2014	048A2	10-FB	Total	Debris Dam	Too high	12	25	Low Severity
Liberty Reservoir	Norris Run	S	10/10/2014	048A2	17-FB	Temporary	Natural Falls	Too high	18	1	Minor
Liberty Reservoir	Norris Run	S	10/10/2014	048A2	18-FB	Total	Natural Falls	Too high	12	1	Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	01-FB	Total	Debris Dam	Too high	0	2	Low Severity
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	03-FB	Partial	Debris Dam	Too high	8	12	Low Severity
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	05-FB	Total	Debris Dam	Too high	24	1	Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	06-FB	Temporary	Debris Dam	Too high	17	2	Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	13-FB	Total	Road Crossing	Too high	32	1	Low Severity
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	05-FB	Unknown	Natural Falls	Too high	48	6	Low Severity
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	09-FB	Total	Debris Dam	Too high	3	1	Low Severity

Liberty Reservoir SCA Data: Pipe Outfalls														
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	TYPE OF OUTFALL	TYPE OF PIPE	LOCATION	PIPE DIAM (IN)	CHANNEL WIDTH (FT)	EVIDENCE OF DISCHARGE	COLOR	ODOR	SEVERITY
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	15-PO	Other	Smooth Metal Pipe	Right Bank	2	4	Y	Clear	None	Moderate
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	26-PO	Agricultural	Other	Right Bank	4	6	Y	Clear	None	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	29-PO	Agricultural	Other	Right Bank	4	6	N		None	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B1	04-PO	Agricultural	Concrete Pipe	Left Bank	48	0	N			Minor
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	22-PO	Other	Plastic	Left Bank	10	3	N	Clear		Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	26-PO	Agricultural	Other	Right Bank	4	3	N		None	Minor
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031B3	04-PO	Agricultural	Smooth Metal Pipe	Right Bank	12	6	N	Clear		Low Severity
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	11-PO	Other	Plastic	Right Bank	6	0	N			Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A2	44-PO	Stormwater	Concrete Pipe	Right Bank	15	0	N			Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A2	51-PO	Stormwater	Other	Right Bank	6	12	N			Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048A2	38-PO	Overflow	Plastic	Right Bank	6	6	Y	Other	None	Moderate
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	14-PO	Agricultural	Other	Right Bank	6	5	N			Minor
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	22-PO	Stormwater	Concrete Pipe	Right Bank	60	30	Y	Clear		Low Severity
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	23-PO	Stormwater	Corrugated Pipe	Right Bank	24	5	Y	Clear		Low Severity
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	04-PO	Stormwater	Corrugated metal	Right Bank	24	2	N		None	Minor

Liberty Reservoir SCA Data: Exposed Pipes													
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	PIPE IS	TYPE OF PIPE	PIPE DIAM (IN)	LENGTH EXPOSED (FT)	PURPOSE OF PIPE	EVIDENCE OF DISCHARGE	COLOR	ODOR	SEVERITY
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	14-EP	Above stream	Smooth Metal	4	7	Unknown	N	Green Brown		Moderate

Liberty Reservoir SCA Data: Channel Alterations													
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	TYPE	BOTTOM WIDTH (FT)	PERENNIAL FLOW	SEDIMENT DEPOSITION	VEGETATION	ROAD CROSSING	CHANNELIZED LENGTH (FT)	SEVERITY
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	18-CA	Other	5	Y	N	Y	Below	32	Minor
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	16-CA	Other	10	Y	Y	Y	Above	15	Moderate
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039A1	20-CA	Channel	2	Y	N	Y	Above	18	Minor
Liberty Reservoir	Cliffs Branch	S	10/1/2014	039A1	18-CA	Channel	5	Y	N	Y	No	25	Minor
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	34-CA	Other	2	Y	N	Y	Both	16	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	031A3	12-CA	Other	0	Y	Y	Y	Both	2	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	19-CA	Other	2	Y	N	Y	Both	5	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031C3	10-CA	Other	18	Y	N	Y	Above	10	Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	47-CA	Concrete	18	Y	N	N	Above	25	Moderate
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	38-CA	Concrete	12	Y	N	N	Above	10	Moderate
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B1	10-CA	Rip-rap	20	Y	N	N	Above	20	Moderate
Liberty Reservoir	Cliffs Branch	S	10/1/2014	031B2	08-CA	Channel	5	Y	Y	Y	No	30	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/17/2014	031B2	18-CA	Other	36	Y	Y	Y	Above	30	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	27-CA	Other	24	Y	N	N	No	10	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	29-CA	Other	12	Y	N	Y	No	20	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031B2	31-CA	Other	36	Y	N	Y	Above	35	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/30/2014	031B2	32-CA	Other	36	Y	N	N	Above	20	Minor
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B2	37-CA	Other	18	Y	N	N	Above	15	Minor
Liberty Reservoir	Cliffs Branch	S	10/13/2014	031B2	40-CA	Other	18	Y	N	N	Above	15	Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	047C2	09-CA	Rip-rap	25	Y	N	Y	No	6	Moderate
Liberty Reservoir	Keyser Run	S	10/2/2014	047C1	05-CA	Concrete	25	Y	N	Y	Above	15	Moderate
Liberty Reservoir	Keyser Run	S	10/6/2014	048A2	35-CA	Rip-rap	20	Y	N	N	Above	15	Low Severity
Liberty Reservoir	Keyser Run	S	10/2/2014	048A2	48-CA	Concrete	18	Y	N	N	Above	35	Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A2	46-CA	Other	24	Y	N	N	Above	10	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	28-CA	Other	3	Y	N	N	Above	15	Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	22-CA	Rip-rap	3	Y	Y	Y	No	10	Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	048A2	05-CA	Rip-rap	3	Y	N	Y	No	30	Minor
Liberty Reservoir	Norris Run	S	9/23/2014	047C2	01-CA	Other	20	Y	Y	Y	Below	30	Moderate
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	01-CA	Other	48	Y	N	Y	Above	20	Low Severity
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	07-CA	Other	36	Y	Y	Y	No	15	Moderate
Liberty Reservoir	Norris Run	S	10/3/2014	048A3	06-CA	Other	24	Y	N	Y	Above	12	Moderate

Liberty Reservoir SCA Data: Channel Alterations													
WATERSHED	**SUBWATERSHED**	**SWAP AREA**	**DATE**	**MAP**	**SITE**	**TYPE**	**BOTTOM WIDTH (FT)**	**PERENNIAL FLOW**	**SEDIMENT DEPOSITION**	**VEGETATION**	**ROAD CROSSING**	**CHANNELIZED LENGTH (FT)**	**SEVERITY**
Liberty Reservoir	Norris Run	S	10/3/2014	048B2	16-CA	Rip-rap	5	Y	N	N	No	200	Low Severity
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	21-CA	Rip-rap	24	Y	N	N	No	95	Moderate
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	02-CA	Concrete	48	Y	Y	Y	Above	40	Minor
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	25-CA	Gabion	12	Y	N	N	Above	12	Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	11-CA	Other	10	Y	N	N	No	131	Moderate
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	19-CA	Other	24	Y	N	N	Above	12	Minor
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	36-CA	Other	24	Y	N	N	No	122	Minor

Liberty Reservoir SCA Data: Unusual Conditions and Comments										
WATERSHED	**SUBWATERSHED**	**SWAP AREA**	**DATE**	**MAP**	**SITE**	**TYPE**	**DESCRIBE**	**NOTES**	**POTENTIAL CAUSE**	**SEVERITY**
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	06-UC	Unusual Condition	Other	ford crossing - ATV	human	Minor
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	08-UC	Comment	Other	tributary confluence can't access due to roses	n/a	Minor
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	10-UC	Unusual Condition	Scum	delta deposit w/ frog-slime pool at wetland confluence	slack water	Minor
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	12-UC	Unusual Condition	Red Flock	iron flock discharge from 3'' hole in bank	ground water	Minor
Liberty Reservoir	Cliffs Branch	S	9/24/2014	039A1	17-UC	Unusual Condition	Other	abandoned remnant channel	nature	Minor
Liberty Reservoir	Cliffs Branch	S	10/7/2014	039B1	48-UC	Unusual Condition	Other	split channel	high flow events	Low Severity
Liberty Reservoir	Cliffs Branch	S	10/16/2014	039A1	30-UC	Unusual Condition	Other	Cut off channel	channel ds	Moderate
Liberty Reservoir	Cliffs Branch	S	10/23/2014	039A1	39-UC	Unusual Condition	Other	cutoff channel		Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	039A1	39-UC	Unusual Condition	Other	cutoff channel, US end	avulsion	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	15-UC	Unusual Condition	Other	cutoff channel, US end	avulsion	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A3	38-UC	Unusual Condition	Other	extraction pipe and frame	human activity	Minor
Liberty Reservoir	Cliffs Branch	S	10/23/2014	031A2	04-UC	Unusual Condition	Other	RIP RAP SEEMINGLY WASHED DOWN STREAM		Minor
Liberty Reservoir	Cliffs Branch	S	10/24/2014	031C2	23-UC	Unusual Condition	Other	MAKESHIFT CROSSING		Minor
Liberty Reservoir	Cliffs Branch	S	11/18/2014	031B3	02-UC	Unusual Condition	Other	4 in Precast Concrete Pressurized Pipe (PCPP) across stream		Low Severity
Liberty Reservoir	Keyser Run	S	10/2/2014	047C1	01-UC	Unusual Condition	Other	Central bar in stream channel		Minor
Liberty Reservoir	Keyser Run	S	10/2/2014	047C1	07-UC	Unusual Condition	Other	Large woody debris jam		Severe
Liberty Reservoir	Keyser Run	S	10/2/2014	048A2	25-UC	Unusual Condition	Other	Large woody debris jam diverting stream		Moderate
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	11-UC	Unusual Condition	Other	ATV crossing		Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	12-UC	Unusual Condition	Other	Black algae		Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	13-UC	Unusual Condition	Other	ATV crossing		Minor
Liberty Reservoir	Keyser Run	S	10/9/2014	048A1	16-UC	Unusual Condition	Other	ATV crossing		Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048B2	20-UC	Comment	Other	road crossing, no channelization, some erosion		Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048B2	28-UC	Unusual Condition	Other	ATV tracks crossing stream		Minor
Liberty Reservoir	Keyser Run	S	10/6/2014	048B2	31-UC	Unusual Condition	Other	ATV tracks crossing stream		Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048B2	33-UC	Unusual Condition	Other	ATV tracks crossing stream		Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048A2	28-UC	Unusual Condition	Other	ATV tracks crossing stream		Low Severity
Liberty Reservoir	Keyser Run	S	10/6/2014	048A2	32-UC	Unusual Condition	Other	downed cables in stream		Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	24-UC	Unusual Condition	Other	Vehicle crossing		Low Severity
Liberty Reservoir	Keyser Run	S	10/16/2014	048B1	33-UC	Comment	Other	8' wooden crossing		Minor
Liberty Reservoir	Keyser Run	S	10/16/2014	048A1	25-UC	Comment	Other	mint patch in stream		Minor
Liberty Reservoir	Norris Run	S	9/23/2014	047C2	03-UC	Comment		rivulet behind wing wall of downstream end of culvert	runoff from road	Minor
Liberty Reservoir	Norris Run	S	9/23/2014	047C2	04-UC	Comment		debris jam upstream of box culvert		Moderate

Liberty Reservoir SCA Data: Unusual Conditions and Comments										
WATERSHED	SUBWATERSHED	SWAP AREA	DATE	MAP	SITE	TYPE	DESCRIBE	NOTES	POTENTIAL CAUSE	SEVERITY
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	12-UC	Unusual Condition	Other	temporary stream crossing	abandoned development site	Severe
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	16-UC	Unusual Condition	Other	large metal tank in stream		Minor
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	18-UC	Unusual Condition	Other	remnant damn structure. stream bypassed to right		Moderate
Liberty Reservoir	Norris Run	S	9/30/2014	048B3	20-UC	Unusual Condition	Other	unknown concrete impoundment		Severe
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	32-UC	Unusual Condition	Oil	oil boom in stream		Low Severity
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	37-UC	Comment		atv tracks into stream		Low Severity
Liberty Reservoir	Norris Run	S	10/3/2014	048B3	53-UC	Comment		atv tracks wind in and out of stream up to this point		Low Severity
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	07-UC	Unusual Condition	Oil	Oil in water		Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	10-UC	Unusual Condition	Other	Ford across utility raw with broken gabion basket; remnant culvert pipe, oil booms on either side	Utility Crossing	Moderate
Liberty Reservoir	Norris Run	S	9/29/2014	048B2	11-UC	Unusual Condition	Other	Utility critical infrastructure on LB		Minor
Liberty Reservoir	Norris Run	S	9/29/2014	048B3	06-UC	Unusual Condition	Other	Irrigation Pipe	Ag Field	Minor
Liberty Reservoir	Norris Run	S	10/10/2014	048A2	16-UC	Comment	Other	male brook trout in stream		Minor
Liberty Reservoir	Norris Run	S	10/10/2014	048A2	19-UC	Unusual Condition	Other	landscaping dumping area		Minor

APPENDIX B:

UPLANDS SURVEY DATA

NEIGHBORHOOD INFORMATION AND RECOMMENDED ACTIONS																										
Sub-watershed	NSA ID	Neighborhood Name	Ac	PSI	ROI	Down-spout Redirect	Rain Barrel	Rain Garden	Stencil	# Inlets	Bay-scape	Lot Canopy Improve-ment	Fertilizer Reduction	% Lawns-High	Pet Waste	Trash Manage-ment	Buffer Impact	Street Trees	Open-Space-Shade-Trees	Park Creation	Parking-Lot-Retrofit	Alley Retrofit	Street Sweeping	Other Action	Lot Size Acres	Impervious Acres
Board-Aspen Run	NSA_S_0101	Arcadia Avenue	16	Moderate	Moderate	N	N	Y	N		Y	Y	N	0	N	N	N	0	0	N	N	N	0	Mapped stream on lot is roadside ditch (no buffer)	1-3	1.6
Cliffs Branch	NSA_S_0201	Armacost	5	Low	Moderate	N	N	Y	N		Y	Y	N	0	N	N	N	0	0	N	N	N	0	None	1/2	4.0
Cliffs Branch	NSA_S_0202	Fairview	10	Moderate	Moderate	N/A	N/A	N/A	N		Y	Y	N	0	N	N	N	0	0	N	N	N	0	7 cars on one property, pallets by road (5010 Frye Rd)	1	2.0
Cliffs Branch	NSA_S_0203	Midsummer Hill	87	Moderate	Moderate	N	N	Y	N	31	Y	Y	Y	50	N	N	N	0	0	N	N	N	0	None	1-3	13.0
Glen Falls Run	NSA_S_0301	Wood Glen	110	Low	High	N	N	Y	Y	6	Y	Y	N	0	N	N	N	0	0	N	N	N	0	None	3-5	16.5
Glen Falls Run	NSA_S_0302	Old Hanover Road	31	Moderate	High	N	N	Y	N		Y	Y	N	0	N	Y	Y	0	0	N	N	N	0	2 lots have cars parked long - term/abandoned	1/2	4.7
Glen Falls Run	NSA_S_0303	Woodridge	90	High	Moderate	N	N	Y	Y	9	Y	Y	Y	50	N	N	N	0	0	N	N	N	0	None	3-5	8.1
Glen Falls Run	NSA_S_0304	Nob Hill	56	Low	High	N	N	Y	Y	9	Y	Y	N	0	N	N	N	0	0	N	N	N	0	None	1-3	11.3
Glen Falls Run	NSA_S_0305	West Gate	6	Low	Moderate	N	N	N	N	10	Y	Y	N	0	N	N	N	4	0	N	N	N	0	potential for additional trees planted along road into development	< 1/4	4.1
Glen Falls Run	NSA_S_0306	Goshen	14	Moderate	High	Y	Y	Y	Y	4	Y	Y	N	0	N	N	N	0	0	N	N	N	0	None	1/2	4.2
Liberty Reservoir-B	NSA_S_0401	Woodleaf	110	Low	Moderate	N/A	N/A	N/A	Y	4	Y	N	N	0	N	N	N	0	0	N	N	N	0	None	3-5	11.0
Keyser Run	NSA_S_0501	Green Hill Farms	84	Moderate	High	N	N	N	Y	11	Y	Y	N	0	N	N	Y	0	0	N	N	N	0	No stream buffer (mowed)-1006 Green Hill Farm; 5-10 foot buffer (mowed)-1020 Green Hill Farm	1-3	12.7
Keyser Run	NSA_S_0502	Gouline	40	Low	Low	N/A	N/A	N/A	N		Y	N	N	0	N	N	N	0	0	N	N	N	0	None	3-5	2.0
Keyser Run	NSA_S_0503	Harvest View	6	High	Low	N	N	N	N	10	Y	N	Y	100	N	N	N	0	0	N	N	N	0	None	N/A	3.6
Keyser Run	NSA_S_0504	Stone Mill	22	Moderate	High	Y	Y	N	N	22	Y	Y	N	0	N	N	N	0	0	Y	N	N	0	Changed neighborhood perimeter to include SWM facility, potential for bioswales to yard inlets	N/A	14.3
Liberty Reservoir-E	NSA_S_0601	Cockeys Mill Road	20	Low	Moderate	N/A	N/A	N/A	N		Y	Y	N	0	N	N	N	0	0	N	N	N	0	None	1-3	2.0
Norris Run	NSA_S_0701	Franklin Valley	109	Low	Moderate	N/A	N/A	N/A	Y	6	Y	N	N	0	N	N	N	0	0	N	N	N	0	None	1-3	5.4

NEIGHBORHOOD INFORMATION AND RECOMMENDED ACTIONS																										
Sub-watershed	NSA ID	Neighborhood Name	Ac	PSI	ROI	Down-spout Redirect	Rain Barrel	Rain Garden	Stencil	# Inlets	Bay-scape	Lot Canopy Improve-ment	Fertilizer Reduction	% Lawns-High	Pet Waste	Trash Manage-ment	Buffer Impact	Street Trees	Open-Space-Shade-Trees	Park Creation	Parking-Lot-Retrofit	Alley Retrofit	Street Sweeping	Other Action	Lot Size Acres	Impervious Acres
Norris Run	NSA_S_0702	Whispering Oaks	117	Moderate	High	N	N	Y	Y	2	Y	Y	Y	25	N	N	N	0	0	N	N	N	0	None	5-10	5.8
Norris Run	NSA_S_0703	Norris Run Woods	30	Low	Low	N	N	N	Y	3	Y	N	N	10	N	N	N	0	0	N	N	N	0	None	1-3	3.3
Norris Run	NSA_S_0704	Glyndon Trace Condo II	21	Moderate	Moderate	Y	Y	N	N	24	Y	Y	N	0	N	N	N	0	0	N	N	N	0	None	< 1/8	13.4
Norris Run	NSA_S_0705	Franklin Station	21	Low	High	N	N	N	N	29	Y	Y	N	0	N	N	N	16	0	Y	N	N	0	Retrofit yard inlet to rain garden/bioswale; potential rain gardens for downspouts draining to open space; SWM facilities unmaintained	1/4	11.7
Norris Run	NSA_S_0706	Helen Baker	10	Low	Low	N	N	N	N		Y	Y	N	0	N	N	N	0	0	N	N	N	0	None	1/2	1.0
Liberty Reservoir-C	NSA_S_0801	Lonach Farm	117	Moderate	Moderate	N	N	N	N		Y	N	N	10	N	N	N	0	0	N	N	N	0	None	3-5	5.9
Timber Run	NSA_S_0901	Saffell Property	88	Moderate	Low	N	N	Y	N	34	Y	Y	Y	50	N	N	N	0	46	Y	N	N	0	Potential tree plantings around SWM facilities	1-3	8.8
Timber Run	NSA_S_0902	Berrymans Lane	14	Moderate	Low	N	N	N	N		Y	Y	N	0	N	N	N	0	0	N	N	N	0	None	1	1.4
Cooks Branch	NSA_S_1001	Deer Cross	112	Low	Low	N	N	N	N	17	Y	N	N	10	N	N	N	0	0	N	N	N	0	None	1-3	5.6
Liberty Reservoir-F	NSA_S_1101	Folly Quarter	160	Moderate	High	N	N	N	Y	19	Y	Y	N	15	N	N	Y	0	4	N	N	N	0	Potential tree plantings in traffic circle; potential encroachment on stream buffer (east of swim club)	1-3	16.0
Liberty Reservoir-F	NSA_S_1102	Beall Property	38	Moderate	Moderate	N/A	N/A	N/A	N		Y	Y	N	0	N	N	N	0	0	N	N	N	0	None	3-5	3.8
Chimney Branch	NSA_S_1201	Wards Chapel Road	55	High	Moderate	N	N	N	N		Y	Y	N	0	N	N	Y	0	0	N	N	N	0	Trash piled up outside multiple outbuildings; potential encroachment to stream buffers	1-3	2.7
Liberty Reservoir-A	NSA_S_1301	Reservoir Ridge	85	Moderate	Moderate	N/A	N/A	N/A	Y	5	Y	Y	N	0	N	N	N	0	0	N	N	N	0	No SWM Facility-Privately owned property	3-5	4.2

NEIGHBORHOOD INFORMATION AND RECOMMENDED ACTIONS																												
Sub-watershed	NSA ID	Neighborhood Name	Ac	PSI	ROI	Down-spout Redirect	Rain Barrel	Rain Garden	Stencil	# Inlets	Bay-scape	Lot Canopy Improve-ment	Fertilizer Reduction	% Lawns-High	Pet Waste	Trash Manage-ment	Buffer Impact	Street Trees	Open-Space-Shade-Trees	Park Creation	Parking-Lot-Retrofit	Alley Retrofit	Street Sweeping	Other Action	Lot Size Acres	Impervious Acres
Locust Run	NSA_S_1401	Barnes Road	32	Low	Low	N/A	N/A	N/A	N		Y	N	N	0	N	N	N	0	0	N	N	N	0	Shipes Lane is a private driveway. Did not have access to these homes.	1-3	4.8
Locust Run	NSA_S_1402	Hernwood	28	Low	Moderate	N	N	N	N		Y	Y	N	0	N	N	N	0	0	N	N	N	0	None	1/2	5.6

INSTITUTION INFORMATION AND RECOMMENDED ACTIONS																
Site ID	Subwatershed	Name	Type	Public/ Private	Nutrient Manage-ment	# Trees for Planting	Storm-water Retrofit	Downspout Disconnect	Impervious Cover Removal	Trash Manage-ment	Storm Drain Marking	Buffer Improve-ment	Follow-up Inspection	Invasive Removal	Pollution Prevention Plan	Notes
ISI_S_0101	Board-Aspen Run	St. Paul's Evangelical Lutheran Church	Faith-based	Private	N	28	Y	Y	N	N	N	N	N	N	N	SWM to receive street flow. No close downstream inlet; Downspout disconnect for a portion of downspouts. Not all downspouts; SWM retrofit to treat parking lot
ISI_S_0201	Cliffs Branch	Boring United Methodist Church	Faith-based	Private	N	0	N	N	N	N	N	N	N	N	N	Only a portion of the church parking lot is in the Liberty Reservoir watershed.
ISI_S_0202	Cliffs Branch	Living Hope Baptist Church	Faith-based	Private	N	104	Y	N	N	N	N	N	N	N	N	SWM would be treating building roof runoff and portion of lawn. Existing inlet downstream of location. Inlet full of grass clippings; tree planting: line drive to church, perimeter of property.
ISI_S_0203	Cliffs Branch	Assoc. Jewish Charities, Camp Milldale/Pearlstone Retreat	Faith-based	Private	N	268	N	N	N	N	Y	Y	N	N	N	Buffer/restoration planting originally 600 saplings. Deer herd ate all but 50. Areas currently un-mowed, meadow; Recommend follow-up by Co. way to improve survival of saplings. Revisit old planting sites. Educate grounds staff on methods for tree survival
ISI_S_0204	Cliffs Branch	Woodenburg Cemetery	Cemetery	Private	N	0	N	N	Y	N	N	N	N	N	N	Strip of asphalt can be removed; entire lot is cemetery
ISI_S_0205	Cliffs Branch	Mt. Gilead United Methodist Church	Faith-based	Private	N	0	N	N	N	N	N	N	N	N	N	Site is built out. No space for any retrofits or plantings. Possible to educate about pervious pavement in the event the parking lot is resurfaced. 80% of lot is impervious, ~60% is parking lot
ISI_S_0301	Glen Falls Run	Owings Mills Harvest Church of God	Faith-based	Private	Y	103	N	N	N	N	N	Y	N	N	N	Future education effort: Correct lawn maintenance. Property has a lot of mowed grass.
ISI_S_0302	Glen Falls Run	Northwest Baptist Church	Faith-based	Private	N	0	N	N	N	N	N	N	N	Y	N	Remove invasive species from stream buffer and from existing SWM facility.
ISI_S_0401	Glen Falls Run	Reisterstown Moose Lodge 1577	Faith-based	Private	N	33	N	N	N	N	N	N	N	N	N	Future education effort: May be opportunity to reach community members for outreach.
ISI_S_0701	Norris Run	Franklin Middle School	Middle School	Public	N	137	Y	N	Y	N	Y	Y	N	Y	N	Parking lot in SW corner of lot needs broken pavement to be removed, could be replaced with pervious pavers
ISI_S_0702	Norris Run	I.S.S.O. Kalupur Dham Shree Swaminarayan Hindu Temple	Faith-based	Private	N	53	Y	N	N	Y	Y	N	N	N	N	Future education effort: grass growing up through parking lot; Sediment accumulating on lot; May be able to put in a new SWM facility in low spot off parking lot.
ISI_S_0703	Norris Run	Franklin Elementary School	Elementary School	Public	N	58	N	Y	Y	N	Y	Y	N	Y	N	Remove invasive species (tear-a-thumb) Impervious removal on south side of lot near stage, asphalt path broken up/overgrown
ISI_S_0704	Norris Run	Reisterstown United Methodist Church	Faith-based	Private	N	0	Y	N	Y	N	Y	N	N	N	N	Future education effort: Inlet has sediment buildup inside; Possible SWM retrofit downgrade of parking lot. Possible SWM retrofit behind church (or plantings).
ISI_S_0705	Norris Run	Baltimore Hebrew Congregation	Cemetery	Private	N	88	Y	N	N	N	Y	N	N	N	N	Parking lot breaking up

INSTITUTION INFORMATION AND RECOMMENDED ACTIONS																	
Site ID	Subwatershed	Name	Type	Public/ Private	Nutrient Manage-ment	# Trees for Planting	Storm-water Retrofit	Downspout Disconnect	Impervious Cover Removal	Trash Manage-ment	Storm Drain Marking	Buffer Improve-ment	Follow-up Inspection	Invasive Removal	Pollution Prevention Plan	Notes
ISI_S_0706	Norris Run	Bible Fellowship Church	Faith-based	Private	N	202	Y	N	N	N	N	N	N	N	N	Possible SWM retrofit in open area next to parking lot; Tree planting behind building without causing view disruption to monument (3 crosses).
ISI_S_0707	Norris Run	Oheb Shalom Memorial Park	Cemetery	Private	N	96	N	N	N	N	Y	N	N	N	N	None
ISI_S_0708	Norris Run	Covenant of Grace Presbyterian Church in America	Faith-based	Private	N	110	Y	N	N	N	N	N	N	N	N	Convert existing pond into a SWM facility to treat parking lot runoff
ISI_S_0709	Norris Run	Reisterstown Library	Municipal Facility	Public	N	5	N	N	Y	N	Y	N	Y	Y	N	Further evaluate outfall erosion and possible stabilization and possible SWM
ISI_S_1001	Cooks Branch	Reisterstown Evergreen Church of the Brethren	Faith-based	Private	N	4	N	Y	N	N	N	N	N	N	N	Parking lot breaking up, a few downspouts have room for disconnection, not all
ISI_S_1002	Cooks Branch	Deer Park United Methodist Church	Faith-based	Private	N	3	N	N	N	N	N	N	N	N	N	None
ISI_S_1301	Liberty Reservoir-A	Liberty Church, PCA and Christian School	Faith-based	Private	N	37	Y	N	Y	N	Y	N	N	N	N	Parking lot could be reconfigured to remove excess impervious and to add SWM to treat parking lot. Potential for bioswales in medians or larger SWM facility at downstream side of parking lot.
ISI_S_1401	Locust Run	Roman Catholic Church	Faith-based	Private	N	0	N	N	N	N	N	N	N	N	N	Old church used for rosary readings and cemetery. No recommended action.
ISI_S_1402	Locust Run	Baltimore Christian Faith Center	Faith-based	Private	N	100	N	Y	N	Y	Y	N	N	N	N	Curb cuts drain to open space, not flush with existing ground parking lot, may cause problem in future
ISI_S_1403	Locust Run	Emmaus Missionary Baptist Church	Faith-based	Private	N	0	N	N	N	N	N	N	N	N	N	Recent tree planting, parking lot just repaved, no recommended action.

HOTSPOT INFORMATION AND RECOMMENDED ACTIONS

Site_ID	Sub-watershed	Hot Spot Status	Refer for Enforce-ment	Follow Up Inspection	Test for IDDE	Education	Check NPDES Permit	On Site Retrofit	PAA	Review SW PAA	Business Type	Category	Vehicle Operations	Outdoor Materials	Waste Manage-ment	Physical Plant	Turf/Land-scaping	Storm-water	Comments
HSI_S_0101	Board-Aspen Run	Not Hotspot	N	N	N	N	N	Y	Y	N	Roller Skating Rink	Commercial	N	N	Y	Y	N	N	Open space for tree planting and possible SWM facility
HSI_S_0201	Cliffs Branch	Not Hotspot	N	N	N	N	N	N	Y	N	Lawn Equipment Store	Commercial	N	Y	Y	N	N	N	PAA: tree planting alongside and back of lot in open grass areas
HSI_S_0202	Cliffs Branch	Potential Hotspot	N	Y	N	N	N	N	N	N	Auto Repair Shop	Commercial	Y	Y	N/A	N/A	N	N/A	Majority of site could not be viewed, behind fence. Follow up inspection.
HSI_S_0203	Cliffs Branch	Potential Hotspot	N	Y	N	N	N	N	N	N	Propane Tank Shop	Commercial	Y	Y	Y	N	N	N	Could not tour the property. Head waters behind the site.
HSI_S_0301																			Were unable to assess the site, private property, no trespassing sign, and nothing visible from roadway
HSI_S_0302	Glen Falls Run	Potential Hotspot	N	N	N	Y	N	N	N	N	Restaurant	Commercial	Y	N	Y	Y	N	N	Portion of secondary driveway breaking up. Remove broken areas and replace with gravel.
HSI_S_0303	Glen Falls Run	Potential Hotspot	N	Y	N	N	N	N	Y	N	Farm	Industrial	Y	Y	Y	Y	N	Y	More thorough investigation needed based on amount of sediment; Bare soil near back of lot appears to have E&S from aerials. Possible plantings along NW property line could aid in stream buffer improvements.
HSI_S_0304	Glen Falls Run	Potential Hotspot	N	N	N	Y	N	Y	N	N	Garden Center	Landscaping	Y	Y	Y	Y	Y	Y	Future education effort: Better storage of soil stockpiling not upstream of inlet (no E&S); inlet located in middle of gravel parking lot. Significant sediment in inlet (catch basin) - possible SWM.
HSI_S_0305	Glen Falls Run	Potential Hotspot	N	Y	N	Y	N	N	Y	Y	Construction	Commercial	Y	Y	Y	Y	Y	Y	Follow-up inspection: someone who can get access; future education: lawn care. bayscaping on front area; PAA: possible inspection needed to verify; A lot of sediment behind building; Could not access back of site. Possible SWM. Possible plantings.
HSI_S_0306	Glen Falls Run	Not Hotspot	N	N	N	N	N	Y	Y	N	N/A	Transport-Related	N/A	N/A	N/A	N	N	N/A	Possible inlet overgrown and covered with trees and rubble. Tree planting in Open Space and possible SWM retrofit (bioswale) to treat parking lot. Need to confirm existence of downstream inlet.
HSI_S_0307	Glen Falls Run	Potential Hotspot	N	Y	N	Y	N	N	N	N	Lumber Mill and Shop	Commercial	Y	Y	Y	Y	N	Y	Overall site looks good. Main concern is excessive amount of sediment on pavement near storm drains.

HOTSPOT INFORMATION AND RECOMMENDED ACTIONS																			
Site_ID	Sub-watershed	Hot Spot Status	Refer for Enforce-ment	Follow Up Inspection	Test for IDDE	Education	Check NPDES Permit	On Site Retrofit	PAA	Review SW PAA	Business Type	Category	Vehicle Operations	Outdoor Materials	Waste Manage-ment	Physical Plant	Turf/Land-scaping	Storm-water	Comments
																			Follow up visit to inspect further.
HSI_S_0501	Keyser Run	Potential Hotspot	N	N	N	Y	N	N	Y	N	Grocery Store	Commercial	N/A	Y	Y	Y	Y	Y	Future education efforts: trash and grease clean-up; Grease spill-litter applied but not removed; Possibility for tree planting next to building-Currently turf.
HSI_S_0502	Keyser Run	Potential Hotspot	N	N	N	N	N	Y	Y	N	Golf Course	Golf Course	Y	N	Y	N	Y	N	PAA: planting in grass strip by parking lot; small parking lot where golf carts are stored could be treated by micro-bioretention facility; possible to convert pond to treatment pond; eroded stream bank downstream, restore stream and increase buffer
HSI_S_0701	Norris Run	Potential Hotspot	N	N	N	Y	N	N	N	N	Landscaping	Commercial	Y	Y	Y	N	Y	N/A	Improve trash management and empty dumpsters more regularly
HSI_S_0702	Norris Run	Not Hotspot	N	N	N	N	N	N	N	N	Power Plant	Industrial	Y	N/A	Y	N	N	N	Power plant is mostly gravel and fields. No opportunity for tree planting due to overhead power lines.
HSI_S_0703	Norris Run	Confirmed Hotspot	N	N	N	Y	N	N	N	Y	Highway Shop	Municipal	Y	Y	Y	Y	N	N	New curb cut leading to riprap w/ cleanouts, possible SWM, need better trash management, review SWPP due to high amount of sediment on pavement
HSI_S_0901	Timber Run			Y							Contractor	Commercial	N/A	N/A	N/A	N/A	N/A	N/A	Were unable to assess the site, private property, no trespassing sign, and nothing visible from roadway
HSI_S_1101	Liberty Reservoir-F	Potential Hotspot	N	N	N	N	N	N	N	N	Nursery	Commercial	Y	Y	Y	Y	Y	N/A	None
HSI_S_1102	Liberty Reservoir-F	Potential Hotspot	N	N	N	Y	N	N	Y	N	Auto Repair Shop	Commercial	Y	Y	Y	Y	N	N/A	Potential for tree planting in the back of the property, better trash management
HSI_S_1401	Locust Run	Potential Hotspot	N	N	N	Y	N	N	N	N	RV Company	Commercial	Y	Y	Y	Y	N	N/A	Site in need of better trash management

APPENDIX C:

SUPPORTING CALCULATIONS FOR NSA ANALYSIS

Supporting Calculations for NSA Analysis

Downspout Disconnection

Table 4-3 in the Liberty Reservoir Watershed Characterization Report summarizes rooftop acres and % of subwatershed rooftop area addressed by downspout redirection for the recommended neighborhoods. The method in which these two columns were calculated is described below.

Rooftop Acres Addressed

Only NSAs recommended for downspout redirection contribute to this analysis. Rooftop acres addressed by redirecting downspouts in a recommended neighborhood were calculated as follows:

Acres of Buildings x % Connected Downspouts

For example, NSA_S_0306 was recommended for downspout redirect and has a total of 1.13 acres of buildings (i.e., rooftop) based on Baltimore County's GIS buildings layer. During the uplands survey, it was estimated that 45% of the downspouts in NSA_S_0306 were directed onto impervious surfaces. Therefore, the total rooftop acres addressed by redirecting downspouts in this neighborhood could be 1.13 acres x 0.45 = 0.51 acres.

In some cases, NSAs encompass more than one subwatershed. The rooftop acres addressed for a given subwatershed is calculated as the total rooftop acres in the NSA multiplied by the proportion of the NSA area within that subwatershed. NSA_S_0504, for example, overlaps Keyser Run and Norris Run where 57.7% of its area is within Keyser Run and 42.3% is within Norris Run. During the uplands survey, it was estimated that 40% of the downspouts in NSA_S_0504 were directed onto impervious surfaces. Given that the neighborhood has 4.15 acres of buildings, the rooftop acres addressed by redirecting downspouts in NSA_S_0504 in Keyser Run were calculated as 4.15 acres x 0.577 x 0.40 = 0.96 acres. The rooftop acres addressed through redirecting downspouts in Norris Run were 4.15 acres x 0.423 x 0.40 = 0.70 acres.

% of Subwatershed Rooftop Area Addressed

For a given subwatershed, the % of subwatershed rooftop area addressed by downspout redirection was calculated as:

(∑ Individual NSA Rooftop Acres Addressed / Total Subwatershed Rooftop Acres) x 100%

The total acres of rooftop within a subwatershed were determined using Baltimore County's GIS buildings layer.

Bayscaping

Table 4-4 in the Liberty Reservoir Watershed Characterization Report summarizes the acres of land and % of subwatershed area addressed by bayscaping for the recommended neighborhoods. The method in which these two columns were calculated is described below.

Acres of Land Addressed

Only NSAs recommended for bayscaping contributed to this analysis. Acres of land addressed by bayscaping in a recommended neighborhood were calculated as follows:

(NSA Total Acres – NSA Impervious Acres) x % Lot Available for Bayscaping

The first expression in parenthesis in the equation above represents the total acres of individual lots in an NSA. According to the Center for Watershed Protection (CWP), the minimum recommended proportion of bayscaping is 10% of an individual lot. Therefore, neighborhoods with less than 10% existing landscaping were recommended for bayscaping. The % Lot Available for Bayscaping was calculated as the % Grass Cover of a typical lot in a recommended NSA as this area could be converted into bayscaping. For example, NSA_S_0101 was recommended for bayscaping and has a total area of 16.0 acres. Based on Baltimore County's GIS layers, there are approximately 0.1 acres of roads and 0.7 acres of buildings in this NSA. This means NSA_S_0101 consists of approximately 16.0 – 0.1 – 0.7 = 15.2 acres of total pervious lots. During the uplands survey, it was estimated that the average lot in NSA_S_0101 consisted of 80% grass cover and 4% landscaping. This means that at a maximum, 15.2 acres x 0.80 = 12.2 acres of land could be addressed by bayscaping in this NSA.

As mentioned previously, some NSAs encompass more than one subwatershed. The acres of land addressed for a given subwatershed is calculated as the total acres of land recommended for bayscaping in the NSA multiplied by the proportion of the NSA area within that subwatershed. NSA_S_0501, for example, overlaps Liberty Reservoir-B and Keyser Run where 37.8% of its area is within Liberty Reservoir-B and 62.2% is within Keyser Run. Given that the neighborhood has 55.6 acres available for bayscaping, the acres of land addressed by bayscaping in NSA_S_0501 in Liberty Reservoir-B were calculated as 55.6 acres x 0.378 = 21.0 acres. The acres of land addressed through bayscaping in Keyser Run were 55.6 acres x 0.622 = 34.6 acres.

% of Subwatershed Area Addressed

For a given subwatershed, the % of the total subwatershed area addressed by bayscaping was calculated as:

(∑ Individual NSA Land Acres Addressed / Total Subwatershed Acres) x 100%

Fertilizer Reduction and Education

Table 4-5 in the Liberty Reservoir Watershed Characterization Report summarizes the acres of land and % of subwatershed area addressed by fertilizer reduction for the recommended neighborhoods. The method in which these two columns were calculated is described below.

Acres of Land Addressed

Only NSAs recommended for fertilizer reduction were included in the analysis (i.e., have more than 20% high maintenance lawns). Acres of land addressed by fertilizer reduction/education in a recommended neighborhood were calculated as follows:

(NSA Total Acres – NSA Impervious Acres) x % Lot Grass Cover x % High Maintenance Lawns

The first expression in the parenthesis above represents the total acres of pervious lots in an NSA. During the uplands assessment, the % of grass cover for a typical lot was estimated along with the % of highly maintained lawn. Multiplying these two percentages with the total pervious area in the NSA yields the acres of lawn that would be addressed via fertilizer reduction. For example, NSA_S_0203 was recommended for fertilizer reduction and has a total area of 87.0 acres. Based on Baltimore County's GIS layers, there are approximately 5.7 acres of road and 4.1 acres of buildings. This means NSA_S_0203 consists of approximately 87.0 – 5.7 – 4.1 = 77.2 acres of pervious lots. During the uplands survey, it was estimated that the average lot in NSA_S_0203 consists of 60% grass cover which equates to 77.2 acres x 0.60 = 46.3 total acres of lawn. It was also noted during the assessment that approximately 50% of the lawns were employing high maintenance lawn practices. So there are roughly 46.3 acres x 0.50 = 23.2 acres of high maintenance lawn that could be addressed by fertilizer reduction in NSA_S_0203.

As mentioned above, some NSAs encompass more than one subwatershed. The acres of land addressed for a given subwatershed is calculated as the total acres of land recommended for fertilizer reduction in the NSA multiplied by the proportion of the NSA area within that subwatershed. NSA_S_0901, for example, overlaps Timber Run and Cooks Branch where 63.0% of its area is within Timber Run and 37.0% is within Cooks Branch. Given that the neighborhood has 33.0 acres of high maintenance lawn, the acres of land addressed by fertilizer reduction/education in NSA_S_0901 in Timber Run were calculated as 33.0 acres x 0.63 = 20.8 acres. The acres of land addressed through fertilizer reduction/education in Cooks Branch were 33.0 acres x 0.37 = 12.2 acres.

% of Subwatershed Area Addressed

For a given subwatershed, the % of the total subwatershed area addressed by fertilizer reduction was calculated as:

(∑ Individual NSA Land Acres Addressed / Total Subwatershed Acres) x 100%

Storm Drain Marking

Table 4-6 in the Liberty Reservoir Watershed Characterization Report summarizes the number of inlets and % of subwatershed inlets addressed by storm drain marking for the recommended neighborhoods. The method in which these two columns were calculated is described below.

Number of Inlets Addressed

In past SWAPs, this section has utilized the Baltimore County OIT GIS layers containing major and minor outfalls within specific subwatersheds to determine an approximate inlet density. However, it was determined based on the upland assessments and visual inspection, that the County GIS data for Liberty Reservoir was incomplete. More inlets were observed in the NSAs than were accounted for in the GIS database. Therefore, the number of inlets in each NSA were counted and recorded during the uplands assessments to determine the total number of inlets addressed.

Some NSAs encompass more than one subwatershed. The number of inlets addressed for a given subwatershed is calculated as the total inlets recommended for stenciling in the NSA multiplied by the proportion of the NSA area within that subwatershed and rounded to the whole number. For example, NSA_S_1101 overlaps Timber Run and Liberty Reservoir-F where 25.5% is located in Timber Run and the remaining 74.5% is located in Liberty Reservoir-F. The inlets addressed were calculated in Timber Run as 19 inlets in the NSA x 0.255 = 5 inlets while the inlets addressed for Liberty Reservoir-F were calculated as 19 inlets in the NSA x 0.745 = 14 inlets.

Shade Trees

Table 4-7 in the Liberty Reservoir Watershed Characterization Report summarizes the number of open space shade trees that could be planted in each subwatershed if these actions were addressed for the recommended neighborhoods. The number of open space shade trees recommended for each neighborhood was estimated during the uplands survey based on available space as described in Section 4.2.3.5. Open space shade trees were estimated at 100 trees per acre.

For NSAs encompassing more than one subwatershed, the total number of recommended open space shade trees was multiplied by the proportion of the NSA area within each subwatershed. For example, NSA_S_0901 overlaps Timber Run and Cooks Branch where 63.0% of its area is within Timber Run and 37.0% is within Cooks Branch. The total number of open space shade trees recommended for NSA_S_0901 was 46 trees. The number of shade trees recommended for NSA_S_0901 in Timber Run was calculated as 46 trees x 0.63 = 29 trees. The number of shade trees recommended for NSA_S_0901 in Cooks Branch was 46 trees x 0.37 = 17 trees.

Lot Canopy Improvement

Table 4-8 in the Liberty Reservoir Watershed Characterization Report summarizes the acres of land and % of subwatershed area addressed by lot canopy improvement for recommended neighborhoods. The method in which these two columns were calculated is described below.

Acres of Land Addressed

Only NSAs recommended for lot canopy improvement contributed to this analysis. Acres of land addressed by lot canopy improvement in a recommended neighborhood were calculated as follows:

(NSA Total Acres – NSA Impervious Acres) x % Lot Available for Lot Canopy Improvement

The first expression in the parenthesis in the equation above represents the total acres of individual, pervious lots in an NSA. According to CWP, the recommended proportion of forest canopy is 40% of an individual lot. Therefore, the % Lot available for Lot Canopy Improvement was calculated as 40% minus the fraction of existing forest canopy of a typical lot in a recommended NSA. Multiplying these two factors yields the total acres of land in an NSA recommended/available for lot canopy improvement. For example, NSA_S_0306 was recommended for lot canopy improvement and has a total area of 14.0 acres. Based on Baltimore County's GIS layers, there are approximately 1.26 acres of roads and 1.13 acres of buildings in this NSA. This means that NSA_S_0306 consists of approximately 14.0 – 1.3 – 1.1 = 11.6 acres of total lots. During the uplands survey, it was estimated that the average lot has 8% forest canopy. This means 40% - 8% = 32% would be recommended for additional lot canopy improvement. This equates to 11.6 acres x 0.32 = 3.7 acres of land that could be addressed by lot canopy improvement in this NSA. This acreage was compared to the total acreage of grass cover in the NSA, to ensure that there was adequate space available for tree planting.

As mentioned above, some NSAs encompass more than one subwatershed. The acres of land addressed for a given subwatershed is calculated as the total acres of land recommended for lot canopy improvement in the NSA multiplied by the proportion of the NSA area within that subwatershed. NSA_S_1301, for example, overlaps Liberty Reservoir-A and Locust Run where 76.5% of its area is within Liberty Reservoir-A and 23.5% of its area is within Locust Run. Given that the neighborhood has 22.5 acres of land recommended for lot canopy improvement, the acres of land addressed by lot canopy improvement in NSA_S_1301 in Liberty Reservoir-A were calculated as 22.5 acres x 0.765 = 17.2 acres. The acres of land addressed through lot canopy improvement in Locust Run were 22.5 acres x 0.235 = 5.3 acres.

<u>% of Subwatershed Area Addressed</u>

For a given subwatershed, the % of the total subwatershed area addressed by lot canopy improvement was calculated as:

(∑ Individual NSA Land Acres Addressed / Total Subwatershed Acres) x 100%

APPENDIX F:

Total Maximum Daily Loads of Phosphorus and Sediments for Liberty Reservoir, Baltimore and Carroll Counties, Maryland and Technical Memorandum: Significant Phosphorus and Sediment Point Sources in the Liberty Reservoir Watershed

Total Maximum Daily Loads of Phosphorus and Sediments for Liberty Reservoir, Baltimore and Carroll Counties, Maryland

FINAL

DEPARTMENT OF THE ENVIRONMENT
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Submitted to:
U.S. Environmental Protection Agency, Region III
Water Protection Division
1650 Arch Street
Philadelphia, PA 19103-2029

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List of Abbreviations

Acre-ft	Acre-feet
Acre-ft/yr	Acre-feet per year
AFO	Animal Feeding Operation
BCDPW	Baltimore City Department of Public Works
BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practice
BOD	Biological Oxygen Demand
CAFO	Confined Animal Feeding Operation
CBLCD	Chesapeake Bay Watershed Land Cover Data
CBOD	Carbonaceous Biochemical Oxygen Demand
CBP	Chesapeake Bay Program
CBP P5.3.2	Chesapeake Bay Program Phase 5.3.2
CCAP	Coastal Change Analysis Program
Chla	Active Chlorophyll *a*
CNMP	Comprehensive Nutrient Management Plan
COMAR	Code of Maryland Regulations
CSO	Combined Sewer Overflow
CV	Coefficient of Variation
CWA	Clean Water Act
DO	Dissolved Oxygen
DS	Dissolved Solids
EOS	Edge-of-Stream
EPA	Environmental Protection Agency
ESD	Environmental Site Design
FIBI	Fish Index of Biotic Integrity
Ft^2	Square feet
Ft^3/s	Cubic Feet per second
GIS	Geographic Information System
HSPF	Hydrological Simulation Program Fortran
in/yr	inches per year
LA	Load Allocation
lbs/day	Pounds Per Day
lbs/yr	Pounds per Year
MAFO	Maryland Animal Feeding Operation
MD 8-Digit	Maryland 8-Digit Watershed
MDE	Maryland Department of the Environment
MDL	Maximum Daily Load
MDP	Maryland Department of Planning
mg/l	Milligrams per Liter
MGS	Maryland Geological Survey
Mi^2	Square miles
MOS	Margin of Safety
MRLC	Multi-Resolution Land Characteristics
MS4	Municipal Separate Storm Sewer System

n	Number
N:P	Nitrogen to Phosphorus Ratio
NH_3	Ammonia
NLCD	National Land Cover Data
NMP	Nutrient Management Plan
NO_{23}	Nitrite plus nitrate
NO_3	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
POM	Particulate Organic Matter
SCS	Soil Conservation Service
SCWQP	Soil Conservation And Water Quality Plan
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
tons/yr	Tons per year
TP	Total Phosphorus
TSD	Technical Support Document
TSI	Trophic State Index
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USGS	United States Geological Survey
W2	CE-QUAL-W2
WIP	Watershed Implementation Plan
WLA	Wasteload Allocation
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
WTP	Water Treatment Plant
WWTP	Waste Water Treatment Plant
µg/l	Micrograms per Liter

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes Total Maximum Daily Loads (TMDLs) for phosphorus and sediments in Liberty Reservoir (basin number 02130907) (2010 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02130907_Liberty_Reservoir). Section 303(d) of the federal Clean Water Act (CWA) and EPA's implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is required to either establish a TMDL of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (CFR 2012b).

The Maryland 8-Digit (MD 8-Digit) Liberty Reservoir watershed consists of:

1) The actual impoundment created behind the Liberty Dam, and
2) The nontidal tributaries within the watershed that drain to the impoundment.

The use of the term "Liberty Reservoir" throughout this report will refer to solely the impoundment created behind Liberty Dam. Use of the term "non-tidal portion of the Liberty Reservoir watershed" will refer to the non-tidal tributaries within the watershed draining to the Reservoir.

The Maryland Department of the Environment (MDE) has identified Liberty Reservoir on the State's 2010 Integrated Report as impaired by sediments - sedimentation/siltation (1996), nutrients - phosphorus (1996), mercury in fish tissue (2002), and metals – chromium and lead (1996) (MDE 2010a). The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Liberty Reservoir is Use I-P (*Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply*) (COMAR 2012d). The non-tidal portion of the Liberty Reservoir watershed has been identified by MDE on the State's 2010 Integrated Report as impaired by bacteria – fecal coliform (mainstem only; 2002) and impacts to biological communities (2004) (MDE 2010a).

The TMDL established herein by MDE will address the 1996 nutrient and sediment listings for Liberty Reservoir, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. A water quality analysis (WQA) for chromium and lead in Liberty Reservoir was approved by the EPA in 2003, and a fecal coliform TMDL for the nontidal portion of the watershed was approved by the EPA in 2009. A TMDL for mercury in fish tissue is currently under development and is scheduled for submittal to EPA in 2012. In the draft 2012 Integrated Report, the listing for impacts to biological communities includes the results of a stressor identification analysis.

This document, upon approval by the EPA, establishes TMDLs for phosphorus and sediments in Liberty Reservoir. The water quality goal of the phosphorus TMDL is to decrease phosphorus inputs to the reservoir to levels that will 1) reduce high chlorophyll *a* (Chla) concentrations associated with excessive algal blooms, and 2) increase dissolved oxygen (DO) concentrations to levels that are supportive of the designated use for the reservoir. The water quality goal of the sediment TMDL for Liberty Reservoir is to increase the useful life of the reservoir for water supply purposes by preserving storage capacity.

The TMDL for total phosphorus (TP) was calculated using a time-variable, two-dimensional water quality eutrophication model, CE-QUAL-W2 (W2), to simulate the water quality response in Liberty Reservoir to various nutrient inputs. The TMDL is based on average annual TP loads for the model simulation period of 2000-2005, which includes both wet and dry years, and thus takes into account a variety of hydrological conditions. Elevated Chla concentrations reflective of eutrophic conditions can occur at any time of year and are resultant from the cumulative impact of phosphorus loadings over a prolonged period of time. Therefore, although daily loads were calculated for the analysis, average annual TP loads are the most appropriate measure for expressing the phosphorus TMDL for Liberty Reservoir. Similarly, the sediment TMDL for Liberty Reservoir, which is based on the calculated phosphorus TMDL and an estimation of how much phosphorus is bound to sediment (i.e., a phosphorus to sediment ratio), is expressed as an average annual load in keeping with the long-term water quality goal of preserving the storage capacity of the reservoir. The Maximum Daily Loads (MDLs) associated with the long-term average annual phosphorus and sediment TMDLs, which were calculated for the reservoir as part of this analysis, are provided in Appendix D.

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2012b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable. The phosphorus and sediment loading rates applied within the analysis are reflective of long term average annual loads, and the water quality response in the reservoir to various nutrient inputs was modeled using a continuous simulation model with a six year simulation period from 2000-2005. The six year simulation period encompasses seasonal variations and a range of hydrological and meteorological conditions, including a very dry year (2002) and very wet years (2003 and 2004). Thus, critical conditions and seasonality are implicitly addressed in the analysis.

EPA's regulations require TMDLs to be presented as a sum of waste load allocations (WLAs) for permitted point sources and load allocations (LAs) for nonpoint sources generated within the assessment unit accounting for natural background, tributary, and adjacent segment loads. Furthermore, all TMDLs must include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2012b). An explicit MOS set at 5% of the total assimilative loading capacity of the reservoir was applied for the phosphorus TMDL. The MOS for the sediment TMDL is implicit, since the sediment TMDL is based on: 1) a sediment-to-phosphorus reduction ratio of 0.5:1, rather than the 0.7:1 reduction ratio as recommended by EPA, and 2) the sediment TMDL is calculated using not only the conservative reduction ratio but also the individual phosphorus WLAs and LAs, rather than the total Phosphorus TMDL.

Baseline phosphorus and sediment loads for Liberty Reservoir are derived from the Chesapeake Bay Program's Phase 5.3.2 (CBP P5.3.2) Watershed Model 2009 Progress Scenario. The Liberty Reservoir Total Baseline Phosphorus Load is 75,977 pounds per year (lbs/yr). The total baseline phosphorus load is further subdivided into a nonpoint source baseline load (Nonpoint Source BL_{LR}) and three types of point source baseline loads: regulated Concentrated Animal Feeding Operations (CAFO BL_{LR}), National Pollutant Discharge Elimination System (NPDES) regulated stormwater (NPDES Stormwater BL_{LR}) and regulated process water (Process Water BL_{LR}) (see Table ES-1). The Liberty Reservoir Total Baseline Sediment Load is 20,767 tons per year (tons/yr), and is subdivided into the same source categories as the phosphorus baseline load (see Table ES-4). Phosphorus and sediment loads from septic systems are considered to be *de minimis* relative to the total watershed load.

The Liberty Reservoir Average Annual TMDL of Phosphorus is 41,009 lbs/yr. The average annual TMDL is further subdivided into point and nonpoint source allocations and is comprised of a Load Allocation (LA_{LR}) of 24,853 lbs/yr, a CAFO Wasteload Allocation (CAFO WLA_{LR}) of 430 lbs/yr, an NPDES Stormwater Wasteload Allocation (NPDES Stormwater WLA_{LR}) of 11,177 lbs/yr, and a Process Water Wasteload Allocation (Process Water WLA_{LR}) of 2,498 lbs/yr (see Table ES-2). The MOS for the Phosphorus TMDL is 2,050 lbs/yr (5% of the total TMDL). The Liberty Reservoir Average Annual TMDL of Sediment is 15,988 tons/yr, and is comprised of a Load Allocation (LA_{LR}) of 10,438 tons/yr, a CAFO Wasteload Allocation (CAFO WLA_{LR}) of 5 tons/yr, an NPDES Stormwater Wasteload Allocation (NPDES Stormwater WLA_{LR}) of 5,484 tons/yr, and a Process Water Wasteload Allocation (Process Water WLA_{LR}) of 61 tons/yr (see Table ES-5). The MOS for the Sediment TMDL is implicit.

Table ES-1:Liberty Reservoir Baseline Phosphorus Loads (lbs/yr)

Total Baseline Load (lbs/yr)	=	**Nonpoint Source BL_{LR}**	+	**CAFO BL_{LR}**	+	**NPDES Stormwater BL_{LR}**	+	**Process Water BL_{LR}**
75,977	=	51,421	+	1,060	+	20,088	+	3,409

Table ES-2:Average Annual Liberty Reservoir TMDL of Phosphorus (lbs/yr)

TMDL (lbs/yr)	=	**LA_{LR}**	+	**CAFO WLA_{LR}**	+	**NPDES Stormwater WLA_{LR}**	+	**Process Water WLA_{LR}**	+	**MOS**
41,009	=	24,853	+	430	+	11,177	+	2,498	+	2,050

Table ES-3: Liberty Reservoir Baseline Phosphorus Load, TMDL, and Total Reduction Percentage

Baseline Load (lbs/yr)	**TMDL** (lbs/yr)	**Total Reduction** (%)
75,977	41,099	46

Table ES-4: Liberty Reservoir Baseline Sediment Loads (tons/yr)

Total Baseline Load (tons/yr)	=	**Nonpoint Source BL_{LR}**	+	**CAFO BL_{LR}**	+	**NPDES Stormwater BL_{LR}**	+	**Process Water BL_{LR}**
20,767	=	12,720	+	11	+	8,021	+	15

Table ES-5: Average Annual Liberty Reservoir TMDL of Sediment (tons/yr)

TMDL (tons/yr)	=	**LA_{LR}**	+	**CAFO WLA_{LR}**	+	**NPDES Stormwater WLA_{LR}**	+	**Process Water WLA_{LR}**		**MOS**
15,988	=	10,438	+	5	+	5,484	+	61	+	Implicit

Table ES-6: Liberty Reservoir Baseline Sediment Load, TMDL, and Total Reduction Percentage

Baseline Load (tons/yr)	**TMDL** (tons/yr)	**Total Reduction** (%)
20,767	15,988	23

Once the EPA has approved this TMDL, and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place. Section 303(d) of the CWA and current EPA regulations require reasonable assurance that the TMDL and WLAs can and will be implemented. Although the Liberty Reservoir watershed does not deliver significant phosphorus and sediment loads to the Chesapeake Bay, implementation of the Liberty Reservoir TMDLs should benefit from the programs Maryland has implemented to achieve the nitrogen and phosphorus load reductions as required by the EPA established Chesapeake Bay TMDLs (US EPA 2010a). The proposed approach for achieving the Liberty Reservoir reduction targets will be based on deployment of an appropriate selection of the comprehensive implementation strategies described in Maryland's Phase I Watershed Implementation Plan (WIP) (MDE 2010b) and Phase II WIP (MDE 2012a), the centerpieces of the State's "reasonable assurance" of implementation for the Chesapeake Bay TMDL. MDE is also planning on explicitly incorporating the phosphorus and sediment reduction goals for Liberty Reservoir and four other major drinking water reservoirs into the Phase III WIP, which will facilitate meeting the final Chesapeake Bay nutrient and sediment reduction goals by 2025. In addition, Baltimore City, Baltimore County and Carroll County have had in place a formal agreement to manage the reservoir watershed, and since 1984, these agreements have been accompanied by an action strategy with specific commitments from the signatories.

Relative to the required reduction in sediment loads from the NPDES Stormwater WLA, BMP implementation will primarily occur via the municipal separate storm sewer system (MS4) permitting process for medium and large municipalities. MDE intends for the required reduction to be implemented in an iterative process that first addresses those sources with the largest impact to water quality, with consideration given to cost of implementation.

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes Total Maximum Daily Loads (TMDLs) for phosphorus and sediments in Liberty Reservoir (basin number 02130907) (2010 *Integrated Report of Surface Water Quality in Maryland* Assessment Unit ID: MD-02130907_Liberty_Reservoir). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to develop a TMDL for each impaired water quality limited segment (WQLS) on the State's Integrated Report, taking into account seasonal variations, critical conditions, and a protective margin of safety (MOS) to account for uncertainty (CFR 2012b). A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to determine the pollutant load reductions needed to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, protection of aquatic life, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Maryland 8-Digit (MD 8-Digit) Liberty Reservoir watershed consists of:

3) The actual impoundment created behind the Liberty Dam, and
4) The nontidal tributaries within the watershed that drain to the impoundment.

The use of the term "Liberty Reservoir" throughout this report will refer to solely the impoundment created behind Liberty Dam. Use of the term "non-tidal portion of the Liberty Reservoir watershed" will refer to the non-tidal tributaries within the watershed draining to the Reservoir.

The Maryland Department of the Environment (MDE) has identified Liberty Reservoir on the State's 2010 Integrated Report as impaired by sediments - sedimentation/siltation (1996), nutrients - phosphorus (1996), mercury in fish tissue (2002), and metals – chromium and lead (1996) (MDE 2010a). The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Liberty Reservoir is Use I-P (*Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply*) (COMAR 2012d). The non-tidal portion of the Liberty Reservoir watershed has been identified by MDE on the State's 2010 Integrated Report as impaired by bacteria – fecal coliform (mainstem only; 2002) and impacts to biological communities (2004) (MDE 2010a).

The TMDL established herein by MDE will address the 1996 nutrient and sediment listings for Liberty Reservoir, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. A water quality analysis (WQA) for chromium and lead in Liberty Reservoir was approved by the EPA in 2003, and a fecal coliform TMDL for the nontidal portion of the watershed was approved by the EPA in 2009. A mercury TMDL is currently under development and is scheduled for submittal to EPA in 2012. In the draft 2012 Integrated Report, the listing for impacts to biological communities includes the results of a stressor identification analysis.

Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients, particularly nitrogen and/or phosphorus. The nutrients act as a fertilizer, which cause the excessive growth of aquatic plants. These aquatic plants eventually die and decompose, leading to the bacterial consumption of dissolved oxygen (DO). Maryland's 2010 Integrated Report identified phosphorus, not nitrogen, as the specific impairing substance causing the nutrient impairment (i.e., eutrophic state) in the Liberty Reservoir.

This document, upon approval by the EPA, establishes TMDLs for phosphorus and sediments in the Liberty Reservoir. The water quality goal of the phosphorus TMDL is to decrease phosphorus inputs to the reservoir to levels that will 1) reduce high chlorophyll *a* (Chla) concentrations associated with excessive algal blooms, and 2) increase DO concentrations to levels that are supportive of the designated use for the reservoir. The water quality goal of the sediment TMDL for Liberty Reservoir is to increase the useful life of the reservoir for water supply purposes by preserving storage capacity.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Liberty Reservoir watershed is located within the Patapsco River sub-basin of the Chesapeake Bay watershed, within Maryland. The reservoir's watershed drains 104,800 acres of western Baltimore County and eastern Carroll County (see Figure 1) (majority of watershed is located in Carroll County). A dam was constructed on the North Branch Patapsco River in 1953, creating the Liberty Reservoir, which is owned by the Baltimore City Department of Public Works (BCDPW). Water supply intakes in the reservoir feed the BCDPW's Ashburton Water Filtration Plant, which provides drinking water to Baltimore City, Carroll County, and Baltimore County. The reservoir is primarily fed by the North Branch Patapsco River; other tributaries include Beaver Run, Keyer's Run, Prugh Run, Morgan Run, Middle Run, Locust Run, and Cooks Branch. There are several "high quality," or Tier II, stream segments (Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) aquatic life assessment scores > 4 (scale 1-5)) located within the watershed requiring the implementation of Maryland's anti-degradation policy (COMAR 2012e). These include Keyser Run, Cooks Branch, an unnamed tributary to Morgan Run, an unnamed tributary to Little Morgan Run, and portions of Morgan Run, Joe Branch, Little Morgan Run, Middle Run, Beaver Run, the North Branch Patapsco River mainstem, and an unnamed tributary to the North Branch Patapsco River mainstem (MDE 2011). Approximately 1.9% percent of the watershed area is covered by water (i.e., streams, ponds, etc). The total population in the MD 8-digit Liberty Reservoir watershed is approximately 115,288 (US Census Bureau 2010).

Reservoir Characteristics

Several relevant statistics for Liberty Reservoir are provided below in Table 1.

Table 1: Current Physical Characteristics of Liberty Reservoir[1]

Location:	Baltimore County, MD Carroll County, MD Latitude 39° 22' 36" N – At Dam Longitude 76° 53' 30" W – At Dam
Surface Area:	3,106 acres (107,343,000 ft^2)[2]
Normal Reservoir Depth:	132.8 feet
Designated Use:	I-P (Water Supply/Recreation) (COMAR 2012d)
Volume:	132,000 acre-feet
Drainage Area to Reservoir:	164 mi^2 (104,800 acres)[3]
Average Discharge:[4]	20.0 ft^3/s (Discharge over the dam only)

Notes: [1] Sources: Weisberg et al. 1985 and James, Saffer, and Tallman 2001.
[2] ft^2: square feet.
[3] mi^2: square miles.
[4] ft^3/s: feet cubed per second.

Figure 1: Location Map of the Liberty Reservoir Watershed

Geology/Soils

The Liberty Reservoir watershed lies within the north-central Piedmont Plateau physiographic province of Maryland, which is characterized by a gentle to steep rolling topography. The surficial geology of the watershed is composed of hard, crystalline igneous and metamorphic rocks of probable volcanic origin, which consist mainly of schist and gneiss, with smaller amounts of marble (Edwards 1981). The watershed drains in a northwest to southeasterly direction, following the dip of the underlying crystalline bedrock in the Piedmont physiographic province. Ground water is found primarily in the fractures and bedding-plane partings of rocks, but it may also be found in the solutional cavities of limestone and marble deposits (McCoy and Summers 1992).

The soils in the Liberty Reservoir watershed belong primarily to the Baile soil series (59%) and the Chester soil series (40%) (USDA 2006). The Baile soil series consists of soils that are very deep and poorly drained. These soils can be found on upland depressions and foot slopes and were formed in mica schist and granitized schist and gneiss. The Chester soil series consists of deep, well drained soils that are located on upland divides and upper slopes and were formed in materials weathered from micaceous schist (USDA 1976).

Soil type for the Liberty Reservoir watershed is also characterized by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) into four hydrologic soil groups: Group A soils have high infiltration rates and are typically deep well drained/excessively drained sands or gravels; Group B soils have moderate infiltration rates and consist of moderately deep-to-deep and moderately well-to-well drained soils, with moderately fine/coarse textures; Group C soils have slow infiltration rates with a layer that impedes downward water movement, and they primarily have moderately fine-to-fine textures; Group D soils have very slow infiltration rates consisting of clay soils with a permanently high water table that are often shallow over nearly impervious material. The Liberty Reservoir watershed is comprised primarily of Group B soils (81%) with smaller portions of Group C and Group D soils (13% and 6% respectively) (USDA 2006).

2.1.1 Land-Use

Land-Use Methodology

The land-use framework used to develop this TMDL was originally developed for the Chesapeake Bay Program Phase 5.3.2 (CBP P5.3.2) Watershed Model.[1] CBP P5.3.2 land-use was based on two distinct stages of development.

The first stage consists of the development of the Chesapeake Bay Watershed Land-Cover Data (CBLCD) series of Geographic Information System (GIS) datasets. These

[1] The EPA Chesapeake Bay Program developed the first watershed model in 1982. There have been many upgrades since the first phase of this model. The CBP P5.3.2 is the latest version and it was developed to estimate flow, nutrients, and sediment loads to the Bay.

datasets provide a 30 meter resolution raster representation of land-cover in the Chesapeake Bay watershed, based on sixteen Anderson Level two land-cover classes. The CBLCD basemap, representing 2001 conditions, was primarily derived from the Multi-Resolution Land Characteristics (MRLC) Consortium's National Land-Cover Data (NLCD) and the National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program's (CCAP) Land-Cover Data. By applying Cross Correlation Analysis to Landsat 5 Thematic Mapper and Landsat 7 Enhanced Thematic Mapper satellite imagery, the US Geological Survey's (USGS) contractor, MDA Federal, generated CBLCD datasets for 1984, 1992, and 2006 from the baseline 2001 dataset. The watershed model documentation, *Chesapeake Bay Phase 5.3 Community Watershed Model* (US EPA 2010b), describes the development of the CBLCD series in more detail. USGS and NOAA also developed an impervious cover dataset from Landsat satellite imagery for the CBLCD basemap, which was used to estimate the percent impervious cover associated with CBLCD developed land-cover classifications.

The second stage consists of using ancillary information for: 1) the creation of a modified 2006 CBLCD raster dataset, and 2) the subsequent development of the CBP P5.3.2 land-use framework in tabular format. Estimates of the urban footprint in the 2006 CBLCD were extensively modified using supplemental datasets. NAVTEQ street data (secondary and primary roads) and institutional delineations were overlayed with the 2006 CBLCD land-cover and used to reclassify underlying pixels. Certain areas adjacent to the secondary road network were also reclassified based on assumptions developed by USGS researchers, in order to capture residential development (*i.e.*, subdivisions not being picked up by the satellite in the CBLCD). In addition to spatially modifying the 2006 CBLCD, the following datasets were used to supplement the developed land cover data in the final CBP P5.3.2 land-use framework: US Census housing unit data, Maryland Department of Planning (MDP) Property View data, and estimates of impervious coefficients for rural residential properties (determined via a sampling of these properties using aerial photography). This additional information was used to estimate the extent of impervious area in roadways and residential lots. Acres of construction and extractive land-uses were determined independently (Claggett et al. 2012). Finally, in order to develop accurate agricultural land-use acreages, the CBP P5.3.2 incorporated county level US Agricultural Census data (USDA 1982, 1987, 1992, 1997, 2002). The watershed model documentation, *Chesapeake Bay Phase 5.3 Community Watershed Model* (US EPA 2010b), describes these modifications in more detail.

The result of these modifications is that CBP P5.3.2 land-use does not exist in a single GIS coverage; instead, it is only available in a tabular format. The CBP P5.3.2 watershed model is comprised of 30 land-uses. Within each generalized land-use classification, most of the sub-classifications are differentiated only by their nitrogen and phosphorus loading rates. Table 1 summarizes the CBP P5.3.2 land-use acres in the Liberty Reservoir watershed by generalized land-use sector. The land-use acres are based on the CBP P5.3.2 2009 Progress Scenario, which, for the CBP P5.3.2 model, represent current conditions.

Liberty Reservoir Watershed Land-Use Distribution

The land-use distribution in the Liberty Reservoir watershed consists primarily of forest (36.0%), crop land (27.2%), and urban land (31.6%). There are also smaller amounts of pasture (5.0%), animal feeding operations (AFOs) (0.1%), and nurseries (0.1%). A detailed summary of the watershed land-use areas is presented in Table 1, and a land-use map is provided in Figure 2.

Table 2: Land-Use Percentage Distribution for the Liberty Reservoir Watershed

General Land-Use	Detailed Land-Use	Area (acres)	Percent (%)	Grouped Percent of Total (%)
Forest	Forest	36,611	35.6	36.0
	Harvested Forest	369	0.4	
AFOs	Animal Feeding Operations	52	0.1	0.1
CAFOs	Concentrated Animal Feeding Operations	13	0.0	0.0
Pasture	Pasture	5,175	5.0	5.0
Crop	Crop	27,975	27.2	27.2
Nursery	Nursery	152	0.1	0.1
Urban	Construction	1,031	1.0	31.6
	Impervious	5,637	5.5	
	Pervious	25,796	25.1	
Extractive	Extractive	0	0.0	0.0
Total		**102,811**	**100.0**	**100.0**

Figure 2: Land-Use Map for the Liberty Reservoir Watershed

2.2 Source Assessment

The Liberty Reservoir Watershed Total Baseline Phosphorus and Sediment Loads can be subdivided into nonpoint and point source loads. This section summarizes the methods used to derive each of these distinct source categories.

2.2.1 Nonpoint Sources Assessment

In this document, the nonpoint source loads account for phosphorus and sediment loads from unregulated stormwater runoff within the Liberty Reservoir watershed. This section provides the background and methods for determining the nonpoint source baseline loads generated within the Liberty Reservoir watershed (Nonpoint Source BL_{LR}).

General Load Estimation Methodology

Nonpoint source loads entering the Liberty Reservoir were estimated the CBP P5.3.2 Watershed Model. The CBP P53.2 model is a Hydrological Simulation Program Fortran (HSPF) model of Maryland, Virginia, the District of Columbia, and the portions of Pennsylvania, New York, Delaware, and West Virginia in the Chesapeake Bay watershed. Its primary purposes are (1) to determine the sources of nitrogen, phosphorus, and sediment to the Chesapeake Bay, (2) to calculate nutrient and sediment loads to the Chesapeake Bay for use in the Chesapeake Bay Program's (CBP) water quality model, and (3) to provide load allocations as part of nutrient and sediment TMDLs for impaired Chesapeake Bay segments. The HSPF model is described in greater detail in Bicknell et al. (2001), and further information on the development of the CBP P5.3.2 watershed model is included in the model documentation, *Chesapeake Bay Phase 5.3 Community Watershed Model* (US EPA 2010b).

Baseline non-point source phosphorus and sediment loads generated within the Liberty Reservoir watershed are estimated based on the edge-of-stream (EOS) loading rates from the 2009 Progress Scenario of the CBP P5.3.2 watershed model. The 2009 Progress Scenario represents current land-use, loading rates, and Best Management Practice (BMP) implementation within the Chesapeake Bay watershed, simulated using precipitation and other meteorological inputs from the time period of 1991-2000, in order to represent variable hydrological conditions. The 1991-2000 simulation period is used in all Chesapeake Bay TMDL scenarios to represent the impact of variable hydrology and meteorology. The 2009 Progress Scenario is applied as the baseline loading scenario for the Chesapeake Bay TMDLs and is considered to be the best available representation of current conditions.

Forest and Harvested Forest EOS phosphorus loads were revised to make them more compatible with the assumptions used in previous phosphorus TMDLs for the Gunpowder Reservoirs (MDE 2007; ICPRB 2006) and Patuxent Reservoirs (MDE 2008, ICPRB 2008). A separate modeling report, *Modeling Framework for Simulating Hydrodynamics and Water Quality in Liberty Reservoir* (ICPRB 2012), discusses the revision of forest EOS loads in more detail.

2.2.2 Point Source Assessment

A list of 36 active permitted point sources that contribute to the phosphorus and sediment loads in the Liberty Reservoir watershed was compiled using MDE's Permit database. The types of permits identified include individual industrial, individual municipal separate storm sewer systems (MS4s), general industrial stormwater, general MS4s, and general Concentrated Animal Feeding Operations (CAFOs). The technical memorandum to this document entitled *Significant Phosphorus and Sediment Point Sources in the Liberty Reservoir Watershed* lists all the permitted entities identified in the Liberty Reservoir watershed.

The permits can be grouped into three categories: (1) process water, (2) stormwater, and (3) CAFOs. Process water permits can be divided into permits for municipal wastewater treatment plants (WWTPs) and permits for industrial facilities. There are no municipal WWTPs in the watershed; however, there are seven industrial facilities that discharge phosphorus and sediments. Baseline phosphorus and sediment loads (Process Water BL_{LR}) for these industrial facilities were calculated based on monitoring data collected as part of their permit requirements, or best professional judgment. Table 3 lists the current, active process water facilities represented in the CBP P5.3.2 watershed model within the Liberty Reservoir watershed and their estimated phosphorus and sediment loads in the 2009 Progress Scenario. The estimated process water total phosphorus (TP) load is 3,409 pounds per year (lbs/yr) and the process water sediment/total suspended solids (TSS) load is 15 tons per year (tons/yr).

Table 3: CBP P5.3.2 2009 Progress Scenario Phosphorus (lbs/yr) and Sediment Loads (tons/yr) for Process Water Point Source Facilities in the Liberty Reservoir Watershed

Facility Name[1,2]	NPDES #	Permit Type		Baseline Load Type	TP (lbs/yr)	TSS (tons/yr)
CONGOLEUM CORPORATION	MD0001384	Industrial	Individual	Individual	88	1
BTR HAMPSTEAD, LLC	MD0001881	Industrial	Individual	Aggregate	3,321	14
CITY OF WESTMINSTER KOONTZ WELL	MD0058556	Industrial	Individual	Aggregate		
S & G CONCRETE - FINKSBURG PLANT	MDG492472	Industrial	Individual	Aggregate		
CARROLL COUNTY FAMILY YMCA	MDG766057	Industrial	General	Aggregate		
THE BOSTON INN, INC.	MDG766199	Industrial	General	Aggregate		
FOUR SEASONS SPORTS COMPLEX	MDG766210	Industrial	General	Aggregate		
FREEDOM SWIM CLUB	MDG766371	Industrial	General	Aggregate		
GREEN VALLEY SWIM CLUB	MDG766379	Industrial	General	Aggregate		
MCDANIEL COLLEGE	MDG766048	Industrial	General	Aggregate		
GLYNDON TRACE CONDOMINIUMS	MDG766199	Industrial	General	Aggregate		
Total					**3,409**	**15**

Notes: 1 Two municipal Water Treatment Plants (WTPs) (Cranberry WTP, NPDES # MD0067644; and Freedom District WTP, NPDES# MD0067652) have been identified within the watershed, but are not included within the analysis, since they withdraw water from the watershed stream system. Therefore, any TP and TSS loads discharged from the plants are representative of a pass through condition.

2 Two hydrostatic testing permits (Maryland Military Facility – Camp Fretterd, NPDES# MDG675043; and Pearlstone Family Camp, NPDES# MDG675029) have also been identified within the watershed but are not included within the analysis, since they both discharge to groundwater rather than surface water, and therefore there are no potential TP or TSS loadings from the permits.

The stormwater category includes all National Pollutant Discharge Elimination System (NPDES) regulated stormwater discharges. The 25 NPDES Phase I or Phase II stormwater permits (see point source technical memorandum to this document entitled *Significant Phosphorus and Sediment Point Sources in the Liberty Reservoir Watershed*) identified throughout the Liberty Reservoir watershed are regulated based on BMPs and do not include nutrient or TSS limits. The Liberty Reservoir NPDES regulated stormwater loads (NPDES Stormwater BL_{LR}) are estimated using the CBP P5.3.2 Progress Scenario developed land-use acres, loading rates, and BMP implementation information. The total NPDES regulated stormwater TP load is 20,088 lbs/yr and the total sediment/TSS load is 8,021 tons/yr.

Starting in 2009, Maryland began the process of permitting CAFOs under the NPDES program. CAFOs are medium to large animal feeding operations that have some artificial conveyance like a swale or ditch to discharge runoff from feedlots to surface water. Recent EPA regulations require CAFOs to have a NPDES permit. Maryland also designates large animal feeding operations which do not discharge or propose to discharge as Maryland Animal Feeding Operations (MAFOs). It is anticipated that on review many MAFOs will require CAFO permits. Several operators in the Liberty

Reservoir watershed have filed notices of intent (NOI) to apply for permits under Maryland's CAFO or MAFO regulations. Based on the NOIs filed by the reporting deadline of February, 2009, the CBP P5.3.2 watershed model estimates that the current average annual TP load from CAFOs in the Liberty Reservoir watershed is 1,060 lbs/yr, and the average annual sediment/TSS load is 11 tons/yr.

2.2.3 Summary of Phosphorus Baseline Loads

Table 4 summarizes the Liberty Reservoir Baseline Phosphorus Loads, reported in lbs/yr and presented in terms of nonpoint and point source loadings.

Table 4: Liberty Reservoir Baseline Phosphorus Loads (lbs/yr)

Total Baseline Load (lbs/yr)	=	**Nonpoint Source BL_{LR}**	+	**CAFO BL_{LR}**	+	**NPDES Stormwater BL_{LR}**	+	**Process Water BL_{LR}**
75,977	=	51,421	+	1,060	+	20,088	+	3,409

Table 5 presents a breakdown of the Liberty Reservoir Total Baseline Phosphorus Load, detailing loads per land-use and specific source sectors. These loads are derived from the CBP P5.3.2 watershed model 2009 Progress Scenario for the Liberty Reservoir watershed. The largest source of phosphorus to the reservoir is from crop land (36.7%). Other phosphorus sources include urban land (26.4%), forest (9.4%), nurseries (13.4%), pasture (5.5%), process water point sources (4.5%), AFOs (1.1%), and CAFOs (1.4%). There are no combined sewer overflows (CSOs) in the Liberty Reservoir watershed, and phosphorus loads from septic systems are considered insignificant. Therefore, these source sectors are not presented in the breakdown.

Table 5: Liberty Reservoir Detailed Baseline Total Phosphorus Loads

General Land-Use/Source Sector	Detailed Land-Use/Source Sector	Load (lbs/yr)	Percent (%)	Grouped Percent of Total
Forest	Forest	6,885	9.1	9.4
	Harvested Forest	258	0.3	
AFOs	Animal Feeding Operations	831	1.1	1.1
CAFOs	Concentrated Animal Feeding Operations	1,060	1.4	1.4
Pasture	Pasture	4,216	5.5	5.5
Crop	Crop	27,853	36.7	36.7
Nursery	Nursery	10,149	13.4	13.4
Urban[1]	Construction	3,462	4.6	26.4
	Impervious	7,624	10.0	
	Pervious	9,002	11.8	
Extractive	Extractive	0	0.0	0.0
Process Water Point Sources	Industrial	3,409	4.5	4.5
	Municipal	0	0.0	
Atmospheric Deposition	Atmospheric Deposition	1,230	1.6	1.6
Total		**75,977**	**100.0**	**100.0**

Note: [1] The urban land-use load represents the permitted stormwater load.

2.2.4 Summary of Sediment Baseline Loads

Table 6 summarizes the Liberty Reservoir Baseline Sediment Loads, reported in ton/yr and presented in terms of nonpoint and point source loadings.

Table 6: Liberty Reservoir Baseline Sediment Loads (lbs/yr)

Total Baseline Load (tons/yr)	=	Nonpoint Source BL_{LR}	+	CAFO BL_{LR}	+	NPDES Stormwater BL_{LR}	+	Process Water BL_{LR}
20,767	=	12,720	+	11	+	8,021	+	15

Table 7 presents a breakdown of the Liberty Reservoir Total Baseline Sediment Load, detailing loads per land-use and specific source sectors. These loads are derived from the CBP P5.3.2 watershed model 2009 Progress Scenario for the Liberty Reservoir watershed. The largest source of sediment to the reservoir is from crop land (42.6%). Other sediment sources include urban land (38.6%), forest (15.5%), pasture (2.0%), nursery (0.9%), AFOs (0.2%), CAFOs (0.1%), and process water point sources (0.1 %). There are no CSOs in the Liberty Reservoir watershed, and there are no sediment loads from septic systems. Therefore, these source sectors are not presented in the breakdown.

Table 7: Liberty Reservoir Detailed Baseline Total Sediment Loads

General Land-Use/Source Sector	Detailed Land-Use/Source Sector	Load (tons/yr)	Percent (%)	Grouped Percent of Total (%)
Forest	Forest	3,019	14.5	15.5
	Harvested Forest	208	1.0	
AFOs	AFOs	45	0.2	0.2
CAFOs	CAFOs	11	0.1	0.1
Pasture	Pasture	423	2.0	2.0
Crop	Crop	8,842	42.6	42.6
Nursery	Nursery	182	0.9	0.9
Urban[1]	Construction	2,247	10.8	38.6
	Impervious	3,403	16.4	
	Pervious	2,371	11.4	
Extractive	Extractive	0	0.0	0.0
Process Water Point Sources	Industrial	15	0.1	0.1
	Municipal	0	0.0	
Atmospheric Deposition	Atmospheric Deposition	0	0.0	0.0
Total		**20,767**	**100.0**	**100.0**

Note: [1] The urban land-use load represents the permitted stormwater load.

2.3 Water Quality Characterization

2.3.1 Water Quality Monitoring Programs

The Liberty Reservoir watershed was originally listed on Maryland's 1996 303(d) List as impaired by nutrients and sediments from nonpoint sources, with supporting evidence cited in Maryland's 1996 305(b) report. The 1996 305(b) report did not directly state that elevated nutrients and sediments were a concern, and it has been determined that the sediment listing was based on best professional judgment (MDE 2004; DNR 1996). The BCDPW is currently the only entity that monitors water quality in the reservoir. Table 8 summarizes the characteristics of the monitoring programs. BCDPW samples four monitoring stations in the reservoir. Figure 3 shows the locations of these sampling stations.

Water column samples are analyzed for temperature, DO, TP, ammonia (NH_3), nitrate (NO_3), turbidity, and Secchi depth, among other constituents. Samples are not analyzed for phosphorus species and organic or total nitrogen. Starting at the surface, samples are taken every five feet until reaching sixty feet in depth; samples are taken at ten-foot intervals thereafter.

Not every sample is analyzed for the entire suite of parameters. Generally, only field measurements like temperature and DO are measured at every depth sampled. Lab analysis is performed for Chla for each sample collected at the surface and at ten-foot depth intervals down to 50 feet. Chemical analysis is performed on samples collected at the surface and at ten–foot depth intervals down to sixty feet.

Table 8: Summary of BCDPW Liberty Reservoir Monitoring Program

Water Quality Monitoring Characteristic	**Details**
Collection Period	3/98-11/04
Number of Monitoring Stations	4
Temperature and DO measurements/Monitoring Station	Samples taken at approximately 5-10 ft. intervals from surface to bottom
Water quality Samples/Monitoring Station	Samples taken at approximately 10 ft. intervals from surface to bottom
Water Quality Analysis Parameters	NH_3, NO_3, NO_{23}, TP, DS, Chla, Turbidity, Secchi depth[1]

Note: [1] NO_{23}: Nitrite plus Nitrate; DS: Dissolved Solids.

Figure 3: Liberty Reservoir BCDPW Monitoring Stations

2.3.2 Temperature Stratification

Liberty Reservoir regularly exhibits temperature stratification starting in April or May and lasting until November. Stratification sometimes occurs in winter but it does not have a significant effect on water quality at this time. Under stratified conditions during the summer and early fall, bottom waters in the reservoir can become hypoxic, or oxygen deficient, because stable density differences inhibit the turbulent mixing that usually transports oxygen from the surface. Under such conditions, the reservoirs can be divided vertically into a well-mixed surface layer, or epilimnion; a relatively homogeneous bottom layer or hypolimnion; and a transitional zone between them, the metalimnion, characterized by a sharp density gradient.

Contour plots of isotherms effectively illustrate the seasonal position of the well-mixed surface layer, or epilimnion. Figure 4 presents a contour plot of isothermals for BCDPW station NPA0042 in Liberty Reservoir. Contours are shown only for the first 30 feet from the surface. In the winter, isothermal lines are vertical, indicating that the reservoir has a fairly uniform temperature over the first 30 feet of depth. In spring, isothermal lines begin to shift from a vertical alignment to a horizontal alignment, and by May, at depths greater than approximately 15 to 20 feet, they are horizontally parallel to each other. At the surface, isothermal lines run vertically to a depth of 10 to 15 feet; this defines the epilimnion.

Figures A-1 through A-4 in Appendix A present contour plots for each BCDPW monitoring station from 2000 through 2005. Generally, the epilimnion is limited to a depth of 5 to 10 feet in the summer. For the purposes of this analysis, the surface layer is considered to be 10 feet deep, with the understanding that in the spring and fall the epilimnion can extend deeper than 10 feet, and in the summer, it is likely to be shallower. For screening purposes, samples taken at depths of 70 feet or greater are considered to be part of the bottom layer, or hypolimnion.

Figure 4: Liberty Reservoir BCDPW Station NPA0042 Isothermal Contours (2000-2008)

2.3.3 Dissolved Oxygen

Figures A-5 through A-8 in Appendix A show contour plots of DO concentrations at BCDPW stations NPA0042, NPA0059, NPA0067, and NPA0105 in Liberty Reservoir from 2000 through 2005. As demonstrated in these plots, low dissolved oxygen occurs in the Liberty Reservoir hypolimnion regularly (See Section 2.4).

Generally, the low DO concentrations in the hypolimnion are due to two related causes. First is temperature stratification, as explained above; second is the entrainment of low DO waters into the epilimnion. Entrainment refers to the process by which turbulent layers spread into a non-turbulent region (Ford and Johnson 1986). The onset of cool weather causes the epilimnion to increase in depth by entraining water from the metalimnion. This water can be low in oxygen and thereby reduce the DO concentrations in the epilimnion. This can occur any time under stratified conditions when the well-mixed surface layer deepens, often well before the fall overturn, when the surface and bottom layers displace one another, which is typical of many lakes and reservoirs (including Liberty).

Figure 5 shows the DO contours at station BCDPW NPA0042. Figure 4, in the previous section, showed the temperature contour. A comparison of the figures indicates that at the end of August at this particular location, the reservoir was highly stratified, with the well-mixed layer extending to about 10 feet deep. Throughout September, the surface waters cooled, and the epilimnion deepened. The layers with low oxygen concentrations in the summer were drawn into the epilimnion. By October, the epilimnion once again had fairly uniform DO concentrations, although the reservoir had not completely overturned.

Entrainment and the fall overturn account for the other low DO observations in the epilimnion of the Liberty Reservoir. In a typical reservoir system, there is also another factor that can influence entrainment, which is drawdown. Withdrawals from a reservoir can induce currents that enhance mixing. Figure 6 shows the surface elevation of Liberty Reservoir from 2000 through 2005. In 2002 (a drought year), withdrawals from Liberty Reservoir dropped the surface elevation by about ten feet. These drawdowns are more than likely contributing to the low DO concentrations in the well-mixed surface layer of the reservoir.

Figures A-9 through A-12 in Appendix A show time series of DO at the surface and at five-foot intervals up to 10 feet, the screening-level definition of the epilimnion. DO concentrations are above the 5.0 milligrams per liter (mg/l) criterion (See Section 2.4).

Figure 5: Liberty Reservoir BCDPW Station NPA0042 DO Contour (1998-2008)

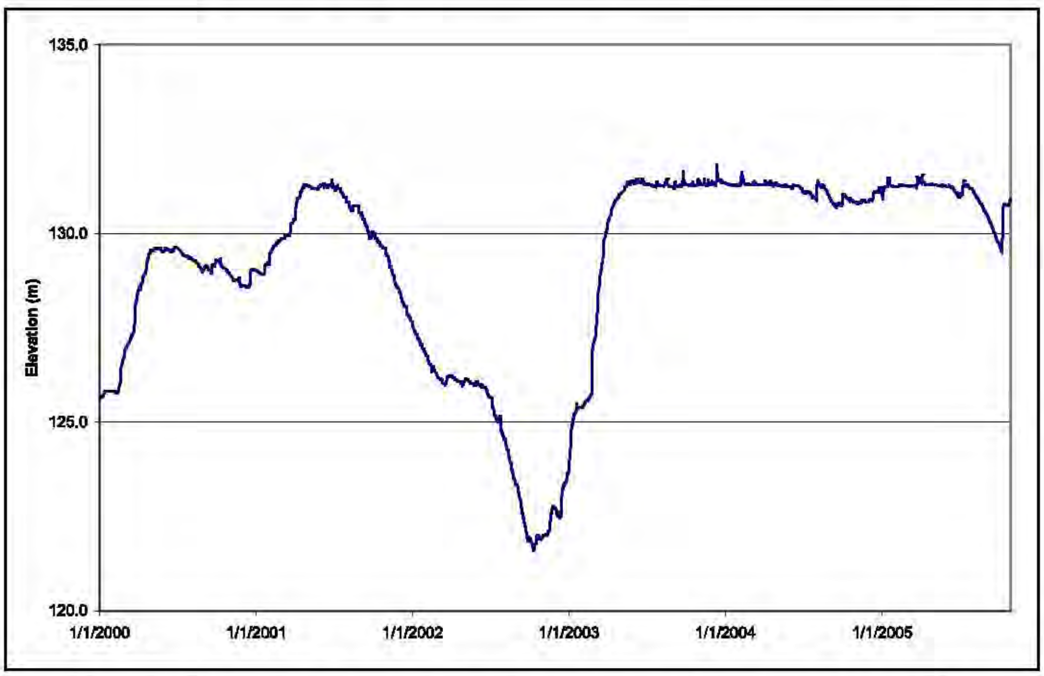

Figure 6: Liberty Reservoir Surface Water Elevation (2000-2005)

2.3.4 Phosphorus

Figures A-13 through A-16 in Appendix A show average TP concentrations at the surface and bottom sampling depths for each monitoring station in Liberty Reservoir from 2000 through 2008. Surface TP concentrations represent an average of the samples taken at depths less than 10-feet. Bottom concentrations represent an average of samples taken at depths of 70 feet or greater. Table 9 provides summary statistics for TP concentrations in Liberty Reservoir.

Table 9: Liberty Reservoir Total Phosphorus Summary Statistics (2000-2008)

Statistic	TP Concentrations (mg/L)						
	Surface Monitoring Stations				Bottom Monitoring Stations		
	NPA0042 (n = 96)[1]	NPA0059 (n = 53)	NPA0067 (n=53)	NPA0105 (n = 96)	NPA0042 (n = 91)	NPA0059 (n = 51)	NPA0067 (n = 45)
Mean	0.024	0.018	0.018	0.035	0.028	0.020	0.021
Standard Deviation	0.038	0.014	0.013	0.053	0.042	0.016	0.013
Minimum	0.005	0.005	0.005	0.004	0.002	0.005	0.005
1st Quartile	0.012	0.011	0.012	0.017	0.014	0.012	0.013
Median	0.015	0.015	0.015	0.022	0.018	0.016	0.017
3rd Quartile	0.023	0.022	0.023	0.031	0.028	0.021	0.023
Maximum	0.354	0.072	0.070	0.440	0.340	0.107	0.064

Note: [1] n: number of samples

2.3.5 Nitrogen

Figures A-17 through A-24 in Appendix A present the average surface and bottom ammonia and nitrate concentrations in Liberty Reservoir from 2000 through 2008. Since the surface layer of the reservoir is not nitrogen limited, bottom ammonia and nitrate concentrations are more relevant as a water quality indicator for two reasons. First, the time series graphs of ammonia concentrations indicate that there are significant releases of ammonia from the bottom sediments. This contributes to greater oxygen demand. Although observed ammonia concentrations were as high as 0.9 mg/l, Maryland's ammonia water quality criteria (COMAR 2012c) were never exceeded. Second, for the most part, nitrate concentrations remained above 0.5 mg/l. Nitrate is preferred to ferric iron (III) as an electron acceptor in diagenesis. The phosphate attached to the bottom sediments is bound to the sediment via ferric iron. It is not likely that phosphate will detach from sediment until ferric iron concentrations are reduced via diagenesis. Therefore, the phosphorus release rate from the sediments in the reservoir should remain low.

2.3.6 Nutrient Limitation

Nitrogen and phosphorus are essential nutrients for algal growth. If one nutrient is available in great abundance relative to the other, then the nutrient that is less available limits the amount of plant matter that can be produced, and it is said to be the "limiting nutrient". The amount of the nutrient in greater abundance does not matter because both nutrients are needed for algal growth. In general, a Total Nitrogen: Total Phosphorus (TN:TP) ratio in the range of 5:1 to 10:1 by mass indicates that plant growth is not limited by phosphorus or nitrogen concentrations. If the TN:TP ratio is greater than 10:1, phosphorus tends to be limiting; if the N:P ratio is less than 5:1, nitrogen tends to be limiting (Chiandani et al. 1974).

Since there are no data available for organic nitrogen concentrations in the reservoir, nitrate is substituted for total nitrogen (TN) in the TN:TP ratio assessment, and the TN:TP ratio is thereby inherently underestimated. In Liberty Reservoir, only about 7% of the samples taken at the 10- and 20-foot depths have NO_3:TP ratios less than 10:1, which is applied as the threshold for distinguishing nitrogen limitation from phosphorus limitation. The median NO_3:TP ratio in Liberty Reservoir is 38:1. Storm events are likely to have high concentrations of particulate nitrogen and phosphorus, but while particulate phosphorus is accounted for in NO_3:TP ratios, particulate organic nitrogen is not. Storm events therefore inflate TP concentrations and exacerbate the underestimation of TN, so the resultant ratios are considered anomalous. Based on the available monitoring data and high N:P ratios, it is clearly evident that Liberty Reservoir is phosphorus limited.

2.3.7 Algae and Chlorophyll α

Figures A-25 through A-28 in Appendix A present the time series graphs of maximum Chla concentrations in the surface layer at the four Liberty Reservoir BCDPW monitoring stations. Chla concentrations tend to be higher in the upstream portion of the reservoir, as represented by station NPA0105 in Figure A-28. Table A-1 in Appendix A presents the maximum Chla concentrations by month and year from 2000 through 2008. As the table indicates, Chla concentrations above 10 micrograms per liter (µg/l) occur regularly, and concentrations above 30 µg/l occur frequently. Concentrations above 10 µg/l occur in every season, but concentrations above 30 µg/l tend to occur more frequently in the summer months.

As per Table A-1, an algal bloom occurred in the winter of 2004 following the extremely wet conditions in 2003. Peak Chla concentrations reached 225 µg/l in the upper reaches of the reservoir at station NPA0105. An analysis of algal taxa performed at the Ashburn WTP showed that there was a significant blue-green algal component in the algal assemblage during the bloom, which is unusual for winter months. The bloom was localized to the upper reaches in the reservoir, as Chla concentrations observed during the bloom at station NPA0042, just upstream of the dam, were below10 µg/l. The magnitude of the bloom in the winter of 2004, the largest observed in the reservoir in the last twenty years, seems unique to the extreme hydrological conditions preceding the event, and it is not considered representative of long-term average conditions in the reservoir.

2.3.8 Sedimentation

The Maryland Geological Survey (MGS) developed new bathymetry for Liberty Reservoir in 2001 (Ortt and Wells 2001). Table 10 summarizes capacity loss and the average sediment accumulation rate for the reservoir.

Table 10: Liberty Reservoir Sedimentation Rates[1]

Capacity Prior to 1953 Construction (acre-ft)[2]	118,148
2001 Capacity (acre-ft)	115,617
Capacity Loss (acre-ft)	2,531
Average Annual Capacity Loss (acre-ft/yr)[3]	54
Sediment Accumulation Rate (in/yr)[4]	0.21

Note: [1]Source: Ortt and Wells 2001.
[2]acre-ft: acres by feet.
[3]acre-ft/yr: acre by feet per year.
[4]in/yr: inches per year.

2.4 Water Quality Impairments

The Maryland water quality standards surface water use designation in COMAR for the Liberty Reservoir is Use I-P (*Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply*) (COMAR 2012d). Maryland's general water quality criteria prohibit the pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere directly or indirectly with designated uses (COMAR 2012b). Excessive eutrophication, as indicated by elevated Chla concentrations, can produce nuisance levels of algae and interfere with designated uses such as fishing and swimming. These algal blooms eventually die off and decompose, and as a result consume oxygen. Excessive eutrophication in Liberty Reservoir is caused by nutrient over enrichment. An analysis of the available water quality data presented in Section 2.3 has demonstrated that phosphorus is the limiting nutrient. In conjunction with excess nutrient inputs, sediment loadings in the watershed are also elevated, which has decreased the projected lifespan of the reservoir. The shortened lifespan of the reservoir violates Maryland's general water quality criteria that prohibits interference with a designated use, specifically, for Liberty Reservoir, the public water supply use.

As per Maryland's water quality criteria for specific water use designations, in Use I-P waters, DO is not allowed to fall below 5.0 mg/l at any time, unless natural conditions result in lower DO concentrations (COMAR 2012a). New DO standards for tidal waters of the Chesapeake Bay and its tributaries take into account stratification and its impact on deeper waters. MDE recognizes that stratified reservoirs and impoundments (there are no natural lakes in Maryland) have conditions similar to stratified tidal waters. Therefore, an interpretation of the existing use I-P standard, to allow for the impact of stratification on DO concentrations, is being applied within this analysis. This interpretation recognizes that low dissolved oxygen in the hypolimnion is due to natural conditions resultant from the morphology of the reservoir, the resulting degree of stratification, and the naturally occurring sources of organic material in the watershed. Therefore, the interpretation of the Use I-P DO standard for non-tidal waters, as applied to reservoirs, is as follows:

- A minimum DO concentration of 5.0 mg/l will be maintained throughout the water column during periods of complete and stable mixing;

- A minimum DO concentration of 5.0 mg/l will be maintained in the mixed surface layer at all times, even during stratified conditions, except during periods of overturn or other naturally-occurring disruptions to the stratification; and
- Hypolimnetic hypoxia will be addressed on a case-by-case basis, taking into account morphology, the degree of stratification, sources of diagenic organic material in reservoir sediments, and other such factors.

Hypoxia occurs when DO concentrations are below levels necessary to support aquatic life. DO concentrations below 2-3 mg/l are considered hypoxic (Committee on Environment and Natural Resources 2010). For the application of the DO standard to Liberty Reservoir, the hypolimnion will be considered hypoxic when DO concentrations are below 2 mg/l.

Analysis of the water quality data presented in Section 2.3 indicates that all observed DO concentrations below 5.0 mg/l in the surface layer of Liberty Reservoir are associated with stratification or the mixing of stratified waters into the surface layer during periods of reservoir overturn or drawdown. However, seasonal hypoxia occurs regularly in the hypolimnion of the reservoir.

3.0 TARGETED WATER QUALITY GOALS

The overall objective of the TMDLs proposed in this document is to reduce phosphorus and sediment loads to levels that support the Use I-P designation for Liberty Reservoir. Specifically, the TMDLs reflect phosphorus and sediment loadings to the reservoir that are in attainment of the applicable DO and Chla water quality criteria for Use I-P waters, appropriately modified based on the stratification of reservoirs and impoundments (See Section 2.4 for further details). The Chla endpoints selected for the reservoir are (1) a ninetieth percentile instantaneous chlorophyll concentration not to exceed 30 μg/l in the surface layer, and (2) a 30-day moving average concentration not to exceed 10 μg/l in the surface layer. A concentration of 10 μg/l corresponds to a score of approximately 53 on the Carlson Trophic State Index (TSI) (Carlson 1977). This is the approximate boundary between mesotrophic and eutrophic conditions, which is an appropriate trophic state at which to manage the reservoir. Mean Chla concentrations exceeding 10 μg/l are associated with Chla peaks exceeding 30 μg/l. These peaks are associated with a shift in algal composition to blue-green assemblages, which present taste, odor, and treatment problems (Walker 1984). Thus, the Chla endpoints should be reflective of conditions void of nuisance algal blooms. The decrease in phosphorus loads is expected to reduce excessive algal growth and therefore prevent violations of the narrative criteria associated with nuisances, such as taste and odor problems.

In summary, the TMDLs for phosphorus and sediment are intended to:

1. Resolve violations of the general, narrative water quality criteria, as it relates to excessive algal growth causing a nuisance, within the Liberty Reservoir, which is associated with the phosphorus enrichment of the reservoir;
2. Resolve violations of the general, narrative water quality criteria, as it relates to the preservation of a reservoir's life-span and the public water supply designated use, associated with excess sedimentation in Liberty Reservoir; and
3. Assure that DO levels in Liberty Reservoir are in attainment of the non-tidal Use I-P DO criteria, as appropriately modified for the reservoir.

4.0 TOTAL MAXIMUM DAILY LOADS (TMDLs) AND ALLOCATIONS

4.1 Overview

This section describes how the phosphorus and sediment TMDLs and the corresponding allocations were developed for the Liberty Reservoir watershed. Section 4.2 describes the modeling framework for simulating hydrodynamics, nutrient and sediment loads, and water quality responses and resultant assimilative capacity in Liberty Reservoir. Section 4.3 describes the scenarios developed on the basis of modeling results. Section 4.4 explains how the modeling framework satisfies the requirements that TMDLs take into account critical conditions and seasonality. Section 4.5 explains the calculation of the TMDL loading caps. Section 4.6 details the load allocations, and Section 4.7 explains the rationale for the margin of safety. Finally, Section 4.8 summarizes the phosphorus and sediment TMDLs for Liberty Reservoir.

4.2 Computer Modeling Framework

To develop a TMDL, a linkage must be made between the water quality endpoints (e.g., targets or goals) and the identified sources of phosphorus and sediments. This linkage establishes the cause-and-effect relationship between the pollutant loads to/concentrations in the reservoir and their sources. This relationship can vary seasonally, particularly for nonpoint sources, due to factors such as precipitation. Once this link is established, it provides the estimate of the total loading capacity, or TMDL, of the reservoir (US EPA 1999).

Computer simulation models are often used to provide the linkage between the sources of pollutants and targeted water quality goals. The computer modeling framework used to develop the Liberty Reservoir TMDLs has two elements: (1) a refined version of the CBP P5.3.2 watershed model was used to determine the rate and timing of phosphorus and sediment loads to Liberty Reservoir; and (2) a CE-QUAL-W2 (W2) model of the Liberty Reservoir itself, to simulate the impact of those loads on water quality.

The CBP P5.3.2 watershed model was refined for the Liberty Reservoir watershed. One of the refinements that was made to the model involves the CBP P5.3.2 forest EOS loads. Forest EOS phosphorus loads were refined to make them more compatible with the assumptions used in previous phosphorus TMDLs for the Gunpowder Reservoirs (MDE 2007; ICPRB 2006) and Patuxent Reservoirs (MDE 2008, ICPRB 2008). Furthermore, the CBP P5.3.2 representation of the Liberty Reservoir watershed, represented by a single reach, was refined by subdividing the watershed into 12 sub-basins, each with their own modeled reach. Monitoring data collected by the BCDPW was used to simulate the nutrient and sediment loads in the model's sub-basins. The refined CBP P5.3.2 Liberty Reservoir watershed model is used to estimate flows as well as total suspended solid and nutrient loads from the watershed's sub-basins, which are linked to the two-dimensional W2 model of the reservoir. Further details regarding the development of the refined CBP P5.3.2 Liberty Reservoir watershed model can be found in the modeling report for this

TMDL, *Modeling Framework for Simulating Hydrodynamics and Water Quality in Liberty Reservoir* (ICPRB 2012).

W2 is a laterally averaged, two-dimensional computer simulation model, capable in its most recent formulations of representing the hydrodynamics and water quality of rivers, lakes, and estuaries. It is particularly well-suited for representing the temperature stratification that occurs in reservoirs such as Liberty. The W2 reservoir model was used to simulate not only hydrodynamics and temperature but also eutrophic dynamics as well. The reservoir model uses version 3.2 of W2. Cole and Wells (2003) give a general description of the W2 model.

Liberty Reservoir was represented by 48 active, longitudinal segments in five branches in the W2 model. The segments contain anywhere between two to 45 one-meter thick layers. The simulation period for the model is 2000 to 2005. These six years provide a range of hydrological conditions, including wet years (2003 and 2004), a dry year (2002), and average years (2001 and 2005), thus fulfilling the requirement that TMDLs take into account a variety of hydrological conditions.

State variables in the W2 model include dissolved oxygen, ammonia, nitrate, dissolved inorganic phosphorus, and both dissolved and particulate organic matter (POM) in labile and refractory forms. In addition, a number of inorganic solids, carbonaceous biochemical oxygen demand (CBOD) variables, and algal species can be represented in the model. Organic nitrogen and phosphorus, however, are only implicitly represented through CBOD, organic matter, and algal biomass state variables. In order to preserve a mass balance of all species of phosphorus, the state variables in the W2 models were configured as follows:

1. Inorganic phosphorus attached to silt and clay was modeled as distinct inorganic solids. Sorption between sediment and the water column was not simulated in the model.
2. Three biochemical oxygen demand (BOD) variables were used to represent allochthonous organic matter inputs to the reservoir: (1) labile dissolved BOD, (2) labile particulate CBOD, and (3) refractory particulate CBOD. The concentration of these CBOD inputs was calculated based on the concentration of organic phosphorus in the HSPF model, using the stoichiometric ratio between phosphorus and oxygen demand in the reservoir model.
3. The organic matter state variables were reserved to represent the recycling of nutrients within the reservoir between algal biomass and reservoir nutrient pools. No organic matter, as represented by these variables, was input into the reservoir. They were used to track nutrients released from algal decomposition.

To use the W2 model in this configuration, several minor changes had to be made to the W2 version 3.2 code. Inorganic solids contribute to light extinction, but inorganic solids representing solid-phase phosphorus do not contribute to light extinction over and above the sediment to which they are attached. The W2 code was altered so solid-phase phosphorus would not contribute to light extinction. Second, in the W2 model, sediment oxygen demand (SOD) can be represented as a first-order reaction based on the quantity of labile organic matter that has settled to the bottom of a segment. In the original version 3.2 code, the CBOD variables do not settle and do not contribute to the pool of organic material in the sediments. The code was altered so that (1) CBOD species could be assigned a settling velocity, and (2) labile particulate CBOD contributed to sediment organic matter. Further details regarding the development of the Liberty Reservoir W2 model are discussed in the modeling report for this TMDL, *Modeling Framework for Simulating Hydrodynamics and Water Quality in Liberty Reservoir* (ICPRB 2012.

4.3 Scenario Descriptions and Results

4.3.1 Scenario Descriptions

TMDL development for the Liberty Reservoir consisted of the following four scenarios:

1. **Baseline Scenario**: The Baseline Scenario models the current phosphorus and sediment loads in the Liberty Reservoir watershed. These loads are shown in Tables 5 and 7 for phosphorus and sediments, respectively. The phosphorus and sediment loads from the CBP P5.3.2 2009 Progress Scenario were applied as the Baseline Scenario for the TMDLs. The 2009 Progress Scenario represents current land-use, loading rates, and BMP implementation within the Liberty Reservoir watershed. The scenario is simulated within the CBP P5.3.2 model using precipitation and other meteorological inputs from the time period of 1991 to 2000, in order to represent variable hydrological conditions. The 1991 to 2000 simulation period is used in all Chesapeake Bay TMDL scenarios to represent the impact of variable hydrology and meteorology. The 2009 Progress Scenario is used as the baseline scenario for the Chesapeake Bay TMDL, and it provides the best available representation of current conditions.

2. **Calibration Scenario**: The Calibration Scenario represents the actual phosphorus and sediment loads over the model simulation period of 2000 to 2005. The phosphorus and sediment loads in this scenario were used to calibrate the Liberty Reservoir W2 model. Loads from WWTPs and other point source discharges are based on reported flows and concentrations for the model simulation period. Loads from NPDES regulated urban land, as well as nonpoint source loads from forest and agricultural land, were estimated based on the calibration of the refined CBP P5.3.2 Liberty Reservoir watershed model.

3. **TMDL Scenario**: The TMDL Scenario represents the maximum allowable phosphorus and sediment loads the Liberty Reservoir can receive and still meet water quality standards, as predicted by the reservoir water quality model. Phosphorus and sediment loads from NPDES regulated urban stormwater and forested/agricultural nonpoint sources are reduced in the watershed model until the W2 reservoir model indicates that the relevant water quality conditions are in attainment with their criteria. Loads from process water point sources in the

TMDL Scenario are set based on their Wasteload Allocations (WLAs) specified within the Chesapeake Bay TMDL (EPA 2010a) and Maryland's Phase I and II Watershed Implementation Plans (MDE 2010b, 2012).

4. **All-Forest Scenario**: The All-Forest Scenario simulates the response of the reservoir to phosphorus, sediment, nitrogen, and BOD loads that would occur if all of the land in the reservoir's watersheds were forested (i.e., natural conditions). The All-Forest Scenario is used to determine the extent to which hypoxic conditions in the hypolimnion are a function of current watershed pollutant loadings or reservoir morphology. The All-Forest Scenario constitutes an estimate of hypolimnetic DO concentrations under natural conditions. Flows and temperature were taken from the Calibration Scenario, while constituent loads were taken from the HSPF model simulation, wherein all land in the watershed was converted to forest.

4.3.2 Calibration Scenario Results

The primary function of the Liberty Reservoir W2 model is to link algae biomass, as represented by Chla concentrations, to total phosphorus loads. The models were calibrated conservatively, so as to ensure that simulated Chla concentrations were at least as high as observed concentrations, even if maximum seasonal concentrations were shifted upstream or downstream in simulation, or if they occurred a month earlier or later than the corresponding observed concentrations. The unprecedented 2004 winter bloom, which is unrepresentative of long-term conditions in the reservoir, was not simulated in the W2 model. Figure B-1 in Appendix B compares the observed and simulated maximum Chla concentrations by season at station NPA042. The W2 model captures the maximum seasonal Chla concentrations except during the winters of 2003, 2004, and 2005. The model generally captures the observed peak seasonal average Chla concentrations, though sometimes they are shifted spatially or temporally. Figure B-2 in Appendix B compares the simulated and observed cumulative distributions of Chla concentrations at station NPA042 in Liberty Reservoir.

Figure B-3 compares simulated and observed average surface DO concentrations at station NPA042 in Liberty Reservoir. Figure B-4 shows the simulated and observed average bottom DO concentrations. The figure indicates that the model accurately captures the seasonal trend in bottom DO. The coefficients of determination between the observed and simulated DO concentrations are 0.49 and 0.75 in the surface and bottom layers of the reservoir, respectively.

Appendix C contains time series plots comparing simulated and observed concentrations of phosphate, total phosphorus, nitrate, ammonia, and total nitrogen at all four BCDPW monitoring stations.

4.3.3 TMDL Scenario Results

The Liberty Reservoir W2 model was used to calculate the maximum total phosphorus load the reservoir can assimilate and still meet water quality standards. Simulated phosphorus and sediment loads were reduced until two conditions were met: (1) the ninetieth percentile of simulated Chla concentrations in any W2 model cell did not exceed 30 µg/l, and (2) the 30-day moving average Chla concentration of each W2 model cell within approximately 50 feet of the surface was not greater than 10 µg/l. Figure B-5 in Appendix B compares maximum surface layer Chla concentrations from the Calibration and TMDL Scenarios to the observed maximum surface layer concentrations by date at BCDPW monitoring station NPA042.

The TMDL Scenario was also used to evaluate whether the reservoir would meet the DO criteria for Use I-P waters at the scenario's calculated phosphorus and sediment loadings. Figure B-6 shows the average surface DO concentrations at station NPA042 in Liberty Reservoir, based on a screening depth of ten feet. To more accurately screen for potential violations, the position of the well-mixed surface layer was estimated on a daily basis, thereby providing for a more precise evaluation (daily comparison) in the surface layer of DO concentrations versus the Use I-P DO criterion. Instantaneous DO concentrations were output from all cells in the surface layer at half-day intervals. In the TMDL scenario, there is no cell in the surface layer of the reservoir with an instantaneous DO concentration less than 5.0 mg/l except during periods such as the fall overturn, when the surface layer deepens and entrains water with low DO concentrations from the metalimnion.

Even in the TMDL Scenario, seasonal hypoxia persists in the hypolimnion of Liberty Reservoir. Figure B-7 in Appendix B shows the average bottom DO concentrations at the downstream BCDPW monitoring stations in the reservoir. As the figure indicates, although the average DO concentration in the bottom layer increases in the TMDL Scenario, the reservoir still does not maintain a DO concentration greater than 5.0 mg/l in the hypolimnion throughout the simulation period.

4.3.4 All-Forest Scenario Results

As explained previously in Section 4.3, the purpose of the All-Forest Scenario is to aid in assessing whether hypoxic conditions in the bottom layers of Liberty Reservoir are primarily due to 1) the stratification of the reservoir caused by its morphology, or 2) current nutrient inputs from the reservoir watershed. If hypoxia occurs even under all-forested watershed conditions and associated nutrient loadings, then reservoir stratification is the primary cause of hypoxia in the hypolimnion. Consequently, the reservoir would be meeting the applicable water quality standards for DO in Use I-P waters, as interpreted for reservoirs and impoundment (see Section 2.3 for further details).

Average annual TP loads in the Liberty Reservoir All-Forest Scenario are 24% of the TP loads in the Calibration Scenario. The reduction in average annual loads of POM, the precursor to sediment oxygen demand, is less; average annual POM loads in the Liberty Reservoir All-Forest Scenario are 33% of the load in the Calibration Scenario.

Figure 7 below shows the average bottom DO concentrations in the All-Forest Scenario at one of the downstream monitoring stations in the reservoir. The minimum DO concentration at the monitoring station is also shown. Average DO in the bottom layer of the reservoir improves considerably under the All-Forest Scenario. The minimum DO concentration, however, frequently drops below 5.0 mg/l. Even under the All-Forest Scenario, the hypolimnion remains hypoxic in many (but not all) years of the simulation.

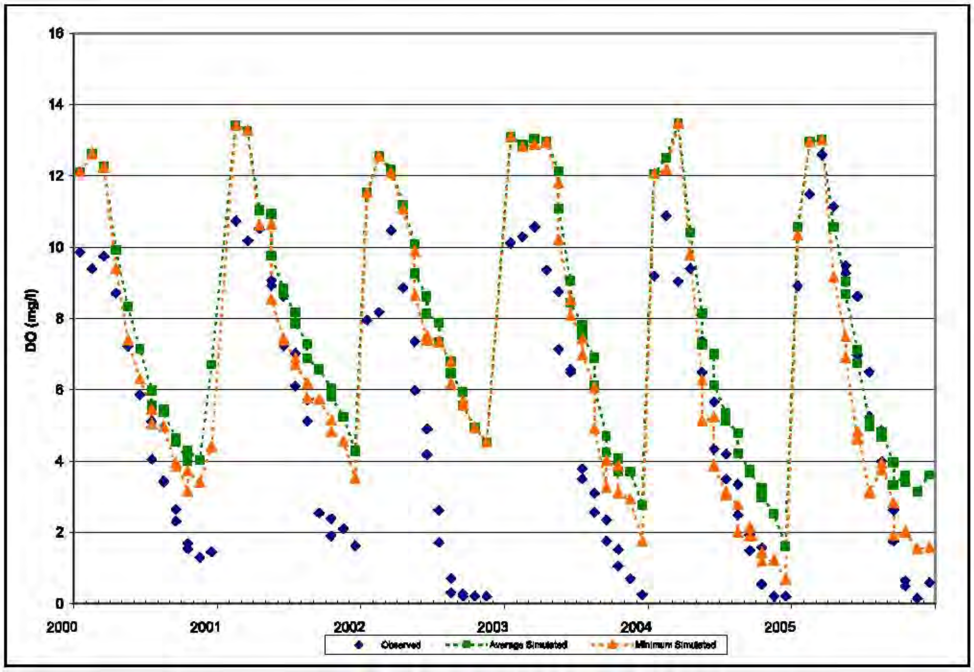

Figure 7: Liberty Reservoir BCDPW Station NPA0042 Observed and Simulated (All-Forest Scenario) Bottom DO Concentrations on Sampling Dates

A sensitivity analysis was performed to better determine how phosphorus and organic matter loading rates impact hypoxia in the hypolimnion. External loading rates of particulate organic matter were reduced to 50%, 20% and 10% of the loads of the All-Forest Scenario, and the percent of sampling dates where DO < 2.0 mg/l at the sampling locations was calculated. Figure 8 shows the results. Hypoxia persists even when loads are reduced to only 20% of the All-Forest Scenario. Although hypoxia disappears when loading rates are 10% of the All-Forest Scenario, 17% of sampling dates under those loading conditions still have DO concentrations less than 5 mg/l in the hypolimnion. The sensitivity analysis shows that low DO in the bottom layers of the reservoirs is relatively insensitive to the particular assumptions used to determine organic matter loads in the models, and demonstrates that hypolimnetic hypoxia is primarily driven by stratification and reservoir morphology, rather than by external loads.

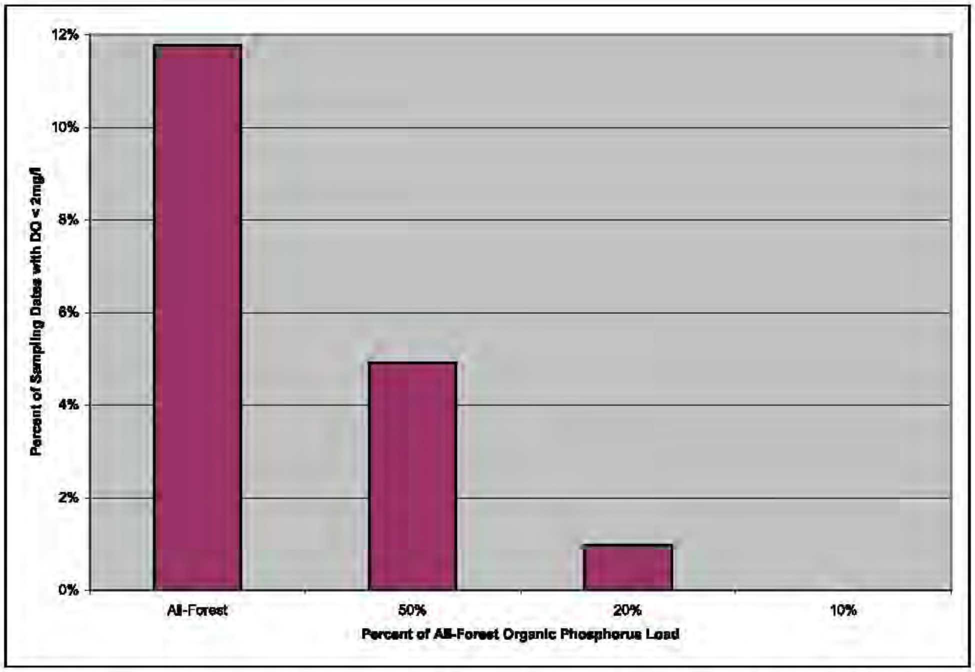

Figure 8: Liberty Reservoir Percent of Sampling Dates on which DO < 2mg/l, as a Function of Percent Particulate Organic Phosphorus

The All-Forest Scenario demonstrates that current phosphorus and sediment loads, and the loads simulated in the TMDL Scenario, do not result in hypoxic conditions that significantly exceed those associated with the natural conditions in the watershed. To an extent, low DO concentrations in the bottom layer of the reservoir are a naturally occurring condition, as described by the interpretation of Maryland's water quality standards for DO in Use I-P waters for reservoirs and impoundments. The TMDL Scenario thus meets water quality standards for DO as per this interpretation.

4.4 Critical Conditions and Seasonality

EPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2012b). The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable.

The phosphorus and sediment loading rates applied within the analysis are reflective of long term average annual loads, and the water quality response in the reservoir to various nutrient inputs was modeled using a continuous simulation model with a six year simulation period from 2000-2005. The six year simulation period encompasses seasonal variations and a range of hydrological and meteorological conditions, including a very dry year (2002) and very wet years (2003 and 2004). Thus, critical conditions and seasonality are implicitly addressed in the analysis.

4.5 TMDL Loading Caps

4.5.1 Phosphorus TMDL Loading Cap

This section presents the average annual phosphorus TMDL for Liberty Reservoir. The TMDL was established based on the modeled phosphorus loadings within the TMDL Scenario, as described in Section 4.3, and the resulting water quality response in the reservoir for the simulated years of 2000 to 2005, which demonstrated achievement of the applicable Chla and DO water quality standards for Use I-P waters. This model simulation time period was used to estimate the TMDL because it is suitable for calculating long-term average loading rates. It includes a dry year as well as very wet years and therefore takes into account a variety of hydrological conditions. Chla concentrations indicative of eutrophic conditions can occur at any time of year, and the model simulation time period encompasses the complete spectrum of observed, seasonal concentrations (see Tables B-1 and B-5 in Appendix B). Low DO concentrations in the hypolimnion that occur seasonally each year are also captured in the model.

In order to attain the phosphorus TMDL loading cap calculated for the reservoir, reductions will be applied to the controllable sources in the watershed. The controllable sources include: (1) NPDES regulated urban land; (2) high till crops, low till crops, hay, and pasture; (3) harvested forest; (4) unregulated AFOs and regulated CAFOS; and (5) industrial process water discharges. If the TMDL loading cap can not be achieved by applying reductions to solely the controllable sources, additional sources might need to be identified and controlled in order to ensure that the water quality standards are attained.

The Liberty Reservoir Total Phosphorus Baseline Load, TMDL, and reduction percentage are presented in Table 11. An overall phosphorus reduction of 46% from current estimated loads will be required to meet the TMDL and attain Maryland's applicable water quality standards for Use I-P waters.

Table 11: Liberty Reservoir Phosphorus TMDL

Baseline Load (lbs/yr)	**TMDL** (lbs/yr)	**Reduction** (%)
75,977	41,009	46

4.5.2 Sediment TMDL Loading Cap

Excess sedimentation reduces a reservoir's storage capacity and therefore negatively impacts its ability to function as a water supply reservoir. Since Liberty Reservoir is a Use I-P waterbody, designated as a public water supply reservoir, this excess sedimentation interferes with the designated use of the waterbody and therefore violates the general, narrative water quality standard applicable to the reservoir. Additionally, excessive sedimentation can also negatively impact a reservoir's fishery and interfere with its recreational uses. Although the maximum sedimentation rates occur during wet weather events, it is the cumulative effect of sedimentation that impacts the reservoir. No single, critical time period can be defined relative to the impact that sedimentation has on water quality in the reservoir. An excessive sedimentation rate negatively impacts a reservoir, regardless of when it occurs. Therefore, efforts to reduce sediment loadings to the reservoir should focus on achieving effective, long-term sediment control. Since measures to control phosphorus can also effectively reduce sedimentation, the expected sediment reduction can be estimated based on the degree of phosphorus control needed to achieve water quality standards in the reservoir.

To quantify the sediment reduction associated with the total required phosphorus reduction for the reservoir, modeling assumptions applied within the CBP P5.3.2 watershed model were applied. For agricultural BMPs that control both phosphorus and sediments, EPA's CBP estimates a 1:1 reduction in sediments, as a result of controlling phosphorus (US EPA 1998). This ratio, however, does not account for phosphorus controls that do not remove sediments.

To estimate the applicable ratio between phosphorus and sediment reductions, it is necessary to estimate the proportion of the phosphorus reduction controls that remove sediments versus those that do not. In general, soil conservation and water quality plans (SCWQPs) remove sediments as well as phosphorus, while nutrient management plans (NMPs) do not. It is assumed that 50% of the phosphorus reduction in the Liberty Reservoir watershed will come from SCWQPs and 50% will come from NMPs. This results in a 0.5:1 ratio of sediment reduction to phosphorus reduction. The net sediment reduction associated with a 46% phosphorus reduction from nonpoint sources is about 23% (0.46 * 0.5 = 0.23).

It is assumed that a reduced sediment loading rate would result in a similar reduction in the sediment accumulation rate in the reservoir. The sediment accumulation rate estimated to result from this reduced loading rate would allow for the retention of 99% of the reservoir's overall, original volume after 40 years.

MDE contends that this volumetric retention will support the Use I-P designated use of Liberty Reservoir: water contact recreation, protection of aquatic life, and public water supply. This estimate is reasonably consistent with technical guidance provided by EPA Region III, which estimates a 0.7:1.0 reduction in sediment relative to phosphorus reductions (US EPA 1998). This rule-of-thumb would yield a 32 % estimated reduction in sediment [100*(0.46 * 0.70) = 32%]

The Liberty Reservoir Sediment TMDL assumes that a 46% reduction in total phosphorus load results in a 23% reduction in sediment load. The Liberty Reservoir Total Sediment Baseline Load, TMDL, and reduction percentage are presented in Table 12.

Table 12: Liberty Reservoir Sediment TMDL

Baseline Load (tons/yr)	**TMDL** (tons/yr)	**Reduction** (%)
20,767	15,988	23%

In order to attain the sediment TMDL loading cap calculated for the reservoir, reductions will be applied to the controllable sources in the watershed. The controllable sources include: (1) NPDES regulated urban land; (2) high till crops, low till crops, hay, and pasture; (3) harvested forest; (4) unregulated AFOS and regulated CAFOS; and (5) industrial process water discharges. If the TMDL loading cap can not be achieved by applying reductions to solely the controllable sources, additional sources might need to be identified and controlled in order to ensure that the water quality standards are attained.

4.6 Load Allocations Between Point and Nonpoint Sources

Per EPA regulation, all TMDLs need to be presented as a sum of WLAs for point sources and Load Allocations (LAs) for nonpoint source loads generated within the assessment unit, as accounting for natural background, tributary, and adjacent segment loads (CFR 2012a). Consequently, the Liberty Reservoir watershed TMDL allocations are presented in terms of WLAs (i.e., point source loads identified within the watershed) and LAs (i.e., the nonpoint source loads within the watershed). The State reserves the right to allocate the TMDL among different sources in any manner that is reasonably calculated to protect the designated use of the reservoir from nutrient and sediment related impacts.

Table 13 summarizes the TMDL Scenario results for phosphorus, and Table 14 summarizes the TMDL Scenario results for sediment. The source categories are based on multiple sources (e.g., high till, low till, and hay are all considered crop sources). In this watershed, crops, pasture, nurseries, NPDES regulated urban land, AFOs, CAFOs, and industrial process water facilities were identified as the predominant controllable sources. Forest is the primary non-controllable source, as it represents the most natural condition in the watershed. Direct atmospheric deposition on water is a minor source that primarily originates outside of the watershed. Atmospheric deposition will be reduced by existing state and federal programs and therefore is not addressed in this TMDL. There are no CSOs in the Liberty Reservoir watershed, and phosphorus and sediment loads from septic systems are considered insignificant.

Table 13: Liberty Reservoir Phosphorus TMDL Reductions by Source Category

Baseline Load Source Categories		Baseline Load (lbs/yr)	TMDL Components	TMDL (lbs/yr)	Reduction (%)
Nonpoint Source	Forest	7,143	LA	6,898	3
	AFOs	831		42	95
	Pasture	4,216		518	88
	Crop	27,853		8,689	69
	Nursery	10,149		7,477	26
	Atmospheric Deposition	1,230		1,230	0
	Extractive	0		0	0
	Subtotal	**51,421**		**24,853**	**52**
Point Source	CAFOs	1,060	WLA	430	59
	Regulated Urban	20,088		11,177	44
	Process Water	3,409		2,498	27
	Subtotal	**24,556**		**14,105**	**43**
MOS[1]				2,050	
Total		**75,977**		**41,009**	**46**

Note: [1] See Section 4.7 for further details regarding the MOS.

Table 14: Liberty Reservoir Sediment TMDL Reductions by Source Category

Baseline Load Source Categories		Baseline Load (lbs/yr)	TMDL Components	TMDL (lbs/yr)	Reduction (%)
Nonpoint Source	Forest	3,228	LA	3,153	2
	AFOs	45		43	5
	Pasture	423		307	27
	Crop	8,842		6,774	23
	Nursery	182		161	12
	Atmospheric Deposition	0		0	0
	Extractive	0		0	0
	Subtotal	**12,720**		**10,438**	**18**
Point Source	CAFOs	11	WLA	5	50
	Regulated Urban	8,021		5,484	32
	Process Water	15		61	0
	Subtotal	**8,047**		**5,550**	**31**
MOS[1]				Implicit	
Total		**20,767**		**15,988**	**23**

Note: [1] See Section 4.7 for further details regarding the MOS.

The Liberty Reservoir TMDLs require a 52% reduction in phosphorus loads and a 18% reduction in sediment loads from nonpoint sources, primarily agricultural land-uses (See Tables 13 and 14). Equal percent reductions were applied to the current controllable loads from nonpoint sources. Current controllable loads were determined as the difference between the CBP P5.3.2 2009 Progress Scenario and the "E3" Scenario, where the E3 Scenario represents the application of all possible BMPs and control technologies to current land-uses and point sources. All of the urban stormwater nutrient and sediment loads within the watershed are regulated via NPDES stormwater permits, and therefore they included in the WLA. For more detailed information regarding the Liberty Reservoir TMDL nonpoint source allocations, please see the technical memorandum to this document entitled "*Significant Phosphorus and Sediment Nonpoint Sources in the Liberty Reservoir Watershed*".

The WLA of the Liberty Reservoir watershed is allocated to three permitted source categories: Process Water WLA, Stormwater WLA, and CAFO WLA. The categories are described below.

Process Water WLA

Process Water permits capable of discharging TP and TSS are assigned to the WLA. There are no municipal WWTPs in the Liberty Reservoir watershed; however, there are eleven industrial process water sources in the watershed that are capable of discharging TP and TSS (four major facilities and seven minor facilities). Within the Chesapeake Bay TMDL, industrial facilities capable of discharging phosphorus or sediment in their process water were assigned a WLA based on monitoring data collected as part of their permit requirements or best professional judgment. These WLAs were adopted for the Liberty Reservoir Phosphorus and Sediment TMDLs.

The Liberty Reservoir Phosphorus TMDL requires a 27% reduction in phosphorus loads from process water sources (See Table 13). No reduction is required in sediment loads from process water sources (See Table 14). Allocations for minor industrial facilities are presented in the Chesapeake Bay TMDL as a watershed-wide aggregate WLA. A similar approach was adopted for the Liberty Reservoir TMDL, and all minor industrial process water facility allocations are represented as a watershed-wide WLA. A list of the industrial process water facilities within the watershed, information pertaining to these permits, information regarding the individual allocations to the major facilities, and information related to the minor facilities included in the aggregate WLA are provided in the technical memorandum to this document entitled "*Significant Phosphorus and Sediment Point Sources in the Liberty Reservoir Watershed*".

Stormwater WLA

Per EPA requirements, "stormwater discharges that are regulated under Phase I or Phase II of the NPDES stormwater program are point sources that must be included in the WLA portion of a TMDL" (US EPA 2002). Phase I and II permits can include the following types of discharges:

- small, medium, and large MS4s – these can be owned by local jurisdictions, municipalities, and state and federal entities (i.e., departments of transportation, hospitals, military bases, etc.),
- industrial facilities permitted for stormwater discharges, and
- small and large construction sites

EPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (US EPA 2002). Therefore, NPDES regulated stormwater loads within the Liberty Reservoir watershed TMDL will be expressed as a single NPDES stormwater WLA. Upon approval of the TMDL, "NPDES-regulated municipal stormwater and small construction storm water discharges effluent limits should be expressed as BMPs or other similar requirements, rather than as numeric effluent limits" (US EPA 2002).

The Liberty Reservoir NPDES Stormwater WLAs are based on reductions applied to the current controllable phosphorus and sediment loads from the urban land-use in the watershed and may include legacy or other sources. Some of these sources may also be subject to controls from other management programs. An equal percent reduction was applied to the controllable loads amongst the predominant, controllable nonpoint sources, as described previously in this section; however, the reduction for the NPDES regulated stormwater source sector was not allowed to exceed 75% of the controllable load, since this has been defined by MDE as the maximum feasible reduction for the individual source sector. The Liberty Reservoir NPDES stormwater WLA requires an overall reduction of 44% for phosphorus (See Table 13) and 32 % for sediment (See Table 14). As stormwater assessment and/or other program monitoring efforts result in a more refined source assessment, MDE reserves the right to revise the current NPDES stormwater WLAs provided the revisions are reasonably calculated to protect the designated use of the reservoir from nutrient and sediment related impacts.

For a detailed list of all NPDES regulated stormwater discharges within the watershed and further information regarding the distribution of NPDES stormwater WLAs among these discharges, please see the technical memorandum to this document entitled "*Significant Phosphorus and Sediment Point Sources in the Liberty Reservoir Watershed*".

CAFO WLA

As per the CWA all CAFOs are required to obtain NPDES permits for their discharges or potential discharges (CFR 2012c). In January, 2009, Maryland implemented new regulations governing CAFOs (COMAR 2012f,g), which were approved by the EPA in January, 2010. Under these regulations, CAFOs are required to fulfill the conditions of a general permit. These conditions include instituting a Comprehensive Nutrient Management Plan (CNMP) that meets the Nine Minimum Standards to Protect Water Quality. The general permit also prohibits the discharge of pollutants, including nutrients, from CAFO production areas except as the result of an event greater than the

25-year, 24-hour storm. For phosphorus, a maximum 75% percent reduction was applied to current controllable loads from CAFOs, and for sediment, an equal percent reduction of current controllable loads was taken from CAFOs as well as from nonpoint sources and regulated stormwater. Overall, a 59% reduction in phosphorus loads and 50% reduction on sediment loads are required from CAFOs in the Liberty Reservoir TMDLs.

4.7 Margins of Safety

All TMDLs must include a margin of safety to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2012b). The MOS shall also account for any rounding errors generated in the various calculations used in the development of the TMDL. The MOS is intended to account for such uncertainties between pollutant loads and water quality response in a manner that is conservative from the standpoint of environmental protection.

Based on EPA guidance, the MOS can be achieved through two approaches (US EPA 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = LA + WLA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis. Maryland has adopted a MOS for nutrient TMDLs using the first approach. The reserved load allocated to the MOS was computed as 5% of the total phosphorus load. The explicit phosphorus MOS for Liberty Reservoir is 2,050 lbs/yr.

In establishing a MOS for sediments, Maryland has adopted an implicit approach by incorporating conservative assumptions. First, because phosphorus binds to sediments, sediment loads will be controlled as a result of controlling phosphorus loads. This estimate of sediment reduction is based on the phosphorus LAs and WLAs, rather than the entire phosphorus TMDL including the MOS. Thus, the explicit 5% MOS for phosphorus will result in an implicit MOS for sediments. This conservative assumption results in a difference of about 280tons/yr (see Section 4.5 above for a discussion of the relationship between the reductions in phosphorus and sediments). Secondly, as described in Section 4.4.2, MDE conservatively assumes a sediment-to-phosphorus reduction ratio of 0.5:1, rather than 0.7:1 estimated in the technical guidance provided by EPA Region III. Table 15 compares the volumetric preservation of the Liberty Reservoir as per the TMDL Scenario with the volumetric preservation of several other approved TMDLs.

Table 15: Sediment TMDL Volumetric Preservation of Impoundments

TMDL	State	VOLUMETRIC PRESERVATION (TMDL time-span)	VOLUMETRIC PRESERVATION (100 year time span)
Urieville Community Lake	Maryland	76% after 40 years	40%
Tony Tank Lake	Maryland	64% – 85% after 40 years	10% to 62.5%
Hurricane Lake	West Virginia	70% after 40 yrs	25%
Tomlinson Run Lake	West Virginia	30% after 40 yrs	Silted in
Clopper Lake	Maryland	98% - 99% after 40 years	96% to 98%
Centennial Lake	Maryland	68% - 87% after 40 years	20% to 69%
Lake Linganore	Maryland	52% - 80% after 40 years	Silted in to 52%
Loch Raven Reservoir	Maryland	85% after 50 years	80%
Triadelphia Reservoir	Maryland	95% after 40 years	87%
Liberty Reservoir	Maryland	99% after 40 years	96%

4.8 Summary of Total Maximum Daily Loads

The Average Annual Liberty Reservoir Phosphorus TMDL is summarized in Table 16. The TMDL is the sum of the LA, NPDES Stormwater WLA, Process Water WLA, CAFO WLA, and MOS. The Maximum Daily Load (MDL) is summarized in Table 17 (See Appendix D for more details).

Table 16: Average Annual Liberty Reservoir Phosphorus TMDL (lbs/yr)

TMDL (lbs/yr)	=	LA_{LR}	+	CAFO WLA_{LR}	+	NPDES Stormwater WLA_{LR}	+	Process Water WLA_{LR}	+	MOS
41,009	=	24,853	+	430	+	11,177	+	2,498	+	2,050

Table 17: Liberty Reservoir Phosphorus MDL (lbs/day)[1]

MDL (lbs/day)	=	LA_{LR}	+	CAFO WLA_{LR}	+	NPDES Stormwater WLA_{LR}	+	Process Water WLA_{LR}	+	MOS
300.3	=	180.0	+	3.1	+	80.9	+	21.2	+	15.0

Note: [1]lbs/day: pounds per day.

The Average Annual Liberty Reservoir Sediment TMDL is summarized in Table 18. The TMDL is the sum of the LA, NPDES Stormwater WLA, Process Water WLA, CAFO WLA, and MOS. The MDL is summarized in Table 19 (See Appendix D for more details).

Table 18: Average Annual Liberty Reservoir Sediment TMDL (tons/yr)

TMDL (tons/yr)	=	**LA_{LR}**	+	**CAFO WLA_{LR}**	+	**NPDES Stormwater WLA_{LR}**	+	**Process Water WLA_{LR}**		**MOS**
15,988	=	10,438	+	5	+	5,484	+	61	+	Implicit

Table 19: Liberty Reservoir Sediment MDL (tons/day)

MDL (tons/day)	=	**LA_{LR}**	+	**CAFO WLA_{LR}**	+	**NPDES Stormwater WLA_{LR}**	+	**Process Water WLA_{LR}**		**MOS**
51.6	=	33.5	+	0.02	+	17.6	+	0.5	+	Implicit

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the CWA and current EPA regulations require reasonable assurance that the TMDL LAs and WLAs can and will be implemented. This section provides the basis for reasonable assurances that the Liberty Reservoir Phosphorus and Sediment TMDLs will be achieved and maintained.

Since 1979, Baltimore City, Baltimore County, and Carroll County have had in place a formal agreement to manage the Liberty Reservoir watershed, and, since 1984, these agreements have been accompanied by an action strategy with specific commitments from the signatories. A revised Reservoir Watershed Management Agreement was signed in 2005, accompanied by a revised Action Strategy. Table 20 lists the parties to the 2005 agreement and some of their major commitments made in the Action Strategy.

Table 20: Signatories to the 2005 Reservoir Management Agreement and the Major Commitments of the 2005 Action Strategy[1]

Maryland Department of the Environment	1. Use NPDES program to discourage significant phosphorus discharges in reservoir watersheds from package plants and new industrial dischargers.
Maryland Department of Agriculture	1. Enforce the provisions of Maryland Water Quality Improvement Act of 1998. 2. Offer assistance through the Maryland Agriculture Cost-Share Program. 3. Target assistance to farm operations having problems with the potential to cause water pollution.
Baltimore City	1. Continue water quality monitoring of reservoirs.
Baltimore County	1. Continued water quality monitoring of tributaries. 2. Maintain Resource Conservation zoning in the reservoir watersheds and maintain insofar as possible the Urban-Rural Demarcation Line. 3. Conduct programs of street-sweeping, storm drain-inlet cleaning, and storm pipe cleaning in urban areas.
Carroll County	1. Require enhanced stormwater management practices for all new development in reservoir watersheds. 2. Use master land-use plans to support Reservoir Management Agreement. 3. Limit insofar as possible additional urban development zoning with the reservoir watersheds.
Baltimore County Soil Conservation District Carroll County Soil Conservation District	1. Encourage farmers to participate in federal and state assistance programs that promote soil conservation and the protection of water quality. 2. Prepare Soil Conservation and Water Quality Plans for each farm in the reservoir watersheds, update plans where necessary, and assist operators in implementing them. 3. Encourage and assist operators to comply with nutrient management plans mandated under the Maryland Water Quality Improvement Act.
Baltimore Metropolitan Council	1. Provide staff for coordination and administration of the Reservoir Technical Program through the financial support of its member jurisdictions.

Note: [1]Source: (RTG 2005)

<u>Maryland Legislative Actions and Funding Programs to Support TMDL Implementation</u>

Maryland recently enacted significant new legislation that requires Phase I MS4 jurisdictions to establish, by July 1, 2013, an annual stormwater remediation fee and a local watershed protection and restoration fund to support implementation of local stormwater management plans. Maryland has made a commitment to include provisions in Phase I and II MS4 permits, due for issuance in 2012, to reduce nutrient and sediment loads from urban stormwater sources.

MD's Water Quality Improvement Act of 1998 (WQIA) requires that comprehensive and enforceable nutrient management plans be developed, approved and implemented for all agricultural lands throughout MD. This act specifically required such plans for nitrogen be developed and implemented by 2002, and plans for phosphorus be completed by 2005.

Additional potential funding sources for implementation include Maryland's Agricultural Cost Share Program (MACS), which provides grants to farmers to help protect natural resources, and the Environmental Quality and Incentives Program, which focuses on implementing conservation practices and BMPs on land involved with livestock and production.

Maryland is also working to adopt a revised Phosphorus Site Index (PSI) and incorporate the new PSI into nutrient management plans in preparation for the 2013 crop season (winter 2012-2013).

To enhance Urban Nutrient Management as a nutrient reduction strategy, the State is working to develop regulations to implement the Fertilizer Use Act. This will: limit nitrogen & phosphorus content in fertilizer content and use on non-agricultural land; require certification and training for non-agricultural applicators; require certain fertilizer product labeling; and require outreach and education programs for homeowner fertilizer use.

Liberty Reservoir Phosphorus and Sediment TMDLs and the Chesapeake Bay TMDL and WIPs

Although the Liberty Reservoir watershed does not deliver significant phosphorus and sediment loads to the Chesapeake Bay, implementation of the Liberty Reservoir TMDLs is expected to benefit from the programs Maryland has put in place to implement the nitrogen and phosphorus load reductions that will be required to meet the Chesapeake Bay TMDL recently established by EPA (US EPA 2010a), as well as Maryland's Phase I and II Watershed Implementation Plans (WIPs), which were developed to provide implementation strategies to achieve the Chesapeake Bay TMDL required nutrient and sediment reductions (MDE 2010b, 2012a).

Maryland had been working with key local partners, including county and municipal staff, soil conservation managers, and a variety of stakeholder organizations and business interests, to help them develop local implementation plans at the county scale. During these interactions, MDE had been emphasizing to the local jurisdictions to focus their efforts on improving water quality in their local rivers, streams, and impoundments. These local plans have been incorporated into the basin-scale implementation plans in the Phase II WIP, which was finalized in July 2012.

Accounting, tracking, and reporting are an important part of the overall WIP strategy, and progress will be closely monitored by tracking both implementation and water quality. This framework of accounting, tracking, and reporting also applies to the Liberty Reservoir phosphorus and sediment TMDLs. This approach provides further assurance that the implementation of the Liberty Reservoir phosphorus TMDL will be achieved through increased accountability and verification of water quality improvements over time.

Certain legislation and funding programs, in addition to those identified previously, have been specifically created relative to the Chesapeake Bay TMDL (US EPA 2010a) and Maryland's Phase I and II WIPs (MDE 2010b,2012a). These pieces of legislation and funding programs are as follows:

Maryland has enacted significant new legislation to increase the Bay Restoration Fund to provide financing for wastewater treatment plant upgrades and on-site septic system improvements, as well as legislation to guide growth of central sewer and septic systems and the application of cover crops by individual farmers. These new laws will support local efforts to reduce nutrient loads in both non-tidal watersheds and in downstream tidal waters of the Chesapeake Bay. In the Liberty Reservoir MD 8-Digit watershed, only the cove crop portion of these funds are applicable, since there are no wastewater treatment plants in the watershed and septic systems have no associated phosphorus loadings, only nitrogen.

In response to the WIPs and the increased burden on local governments to achieve nutrient reduction goals, Maryland has continued to increase funding in the Chesapeake and Atlantic Coastal Bays Trust Fund. For Fiscal Year 2013, in addition to $25 million (pending) for the Trust Fund, $38 million in general obligation bonds were made available to local communities for implementation of stormwater capital improvements. These funds will not only kick start restoration at the local level, but also create and retain green jobs in Maryland's economy. Funding was also increased to support implementation of natural filters on public lands ($9 million), and funding for Soil Conservation Districts from 16 to 39 positions ($2.2 million). In addition, funding for the cover crop program is at $12 million – a record level.

For the 2012-2013 milestone period for the Chesapeake Bay TMDL, Maryland is working to: restrict fall fertilization of small grain crops on soil testing above a given nitrate level thresholds; require incorporation of organic nutrient sources (with some exceptions); limit fall applications of organic nutrient sources; and, require a cover crop following fall applications of organic nutrient sources. Future changes: nutrient application setbacks of 10-35 feet (depending upon application methods) will be required (2014); best management practices will be required for streams with adjacent livestock (2014); winter application of all organic nutrient sources will be prohibited (2016-2020).

NPDES Regulated Stormwater WLA Implementation

Implementation of the required urban sediment and phosphorus load reductions is expected to occur primarily via the Phase I MS4 permitting process for medium and large municipalities, specifically, in this watershed, the Carroll and Baltimore County Phase I MS4 permits, which require the jurisdictions to retrofit 10% of their existing impervious area where there is failing, minimal, or no stormwater management (estimated to be areas developed prior to 1985) every permit cycle, or five years. These Phase I MS4 jurisdictions should work with other regulated stormwater entities in the watershed (please see the technical memorandum to this document entitled "*Significant Point Sources in the Liberty Reservoir Watershed*") during the implementation process to achieve the necessary reductions.

It has been estimated that the average removal efficiencies for BMPs installed between the years of 1985-2002 and post 2002, respectively, which are reflective of the stormwater management regulations in place during these time periods, are 30% and 40% for TP and 50% and 80% for TSS (Claytor and Schueler 1997; Baldwin et al. 2007; Baish and Caliri 2009). Based on these average TP and TSS reduction efficiencies, BMP specific reduction efficiencies as estimated by CBP, and best professional judgment, MDE estimates that future stormwater retrofits, which are expected to be implemented as part of the retrofit requirement to existing impervious land every five years (MDE 2012b), will have approximately a 35% reduction efficiency for TP and a 65% reduction efficiency for TSS. These estimated reduction efficiencies are subject to change over time as technology improves and the amount of data gathered from monitoring these retrofits increases. Additionally, any new development in the watershed will be subject to Maryland's Stormwater Management Act of 2007 and will be required to use environmental site design (ESD) to the maximum extent practicable.

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Appendix A

Figure A-1: Liberty Reservoir BCDPW Station NPA0042 Isothermal Contours (2000–2008)

Figure A-2: Liberty Reservoir BCDPW Station NPA0059 Isothermal Contours (2000–2008)

Figure A-3: Liberty Reservoir BCDPW Station NPA0067 Isothermal Contours (2000-2008)

Figure A-4: Liberty Reservoir BCDPW Station NPA0105 Isothermal Contours (2000-2008)

Figure A-5: Liberty Reservoir BCDPW Station NPA0042 DO Contours (2000-2008)

Figure A-6: Liberty Reservoir BCDPW Station NPA0059 DO Contours (2000-2008)

Figure A-7: Liberty Reservoir BCDPW Station NPA0067 DO Contours (2000-2008)

Figure A-8: Liberty Reservoir BCDPW Station NPA0105 DO Contours (2000-2008)

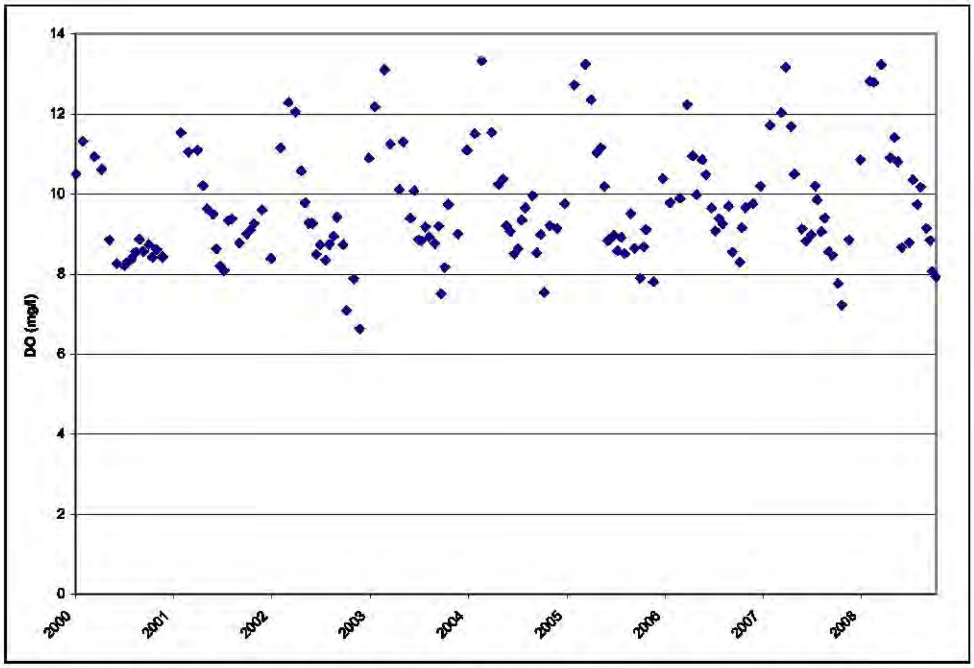

Figure A-9: Liberty Reservoir BCDPW Station NPA0042 Average Surface Dissolved Oxygen (2000-2008)

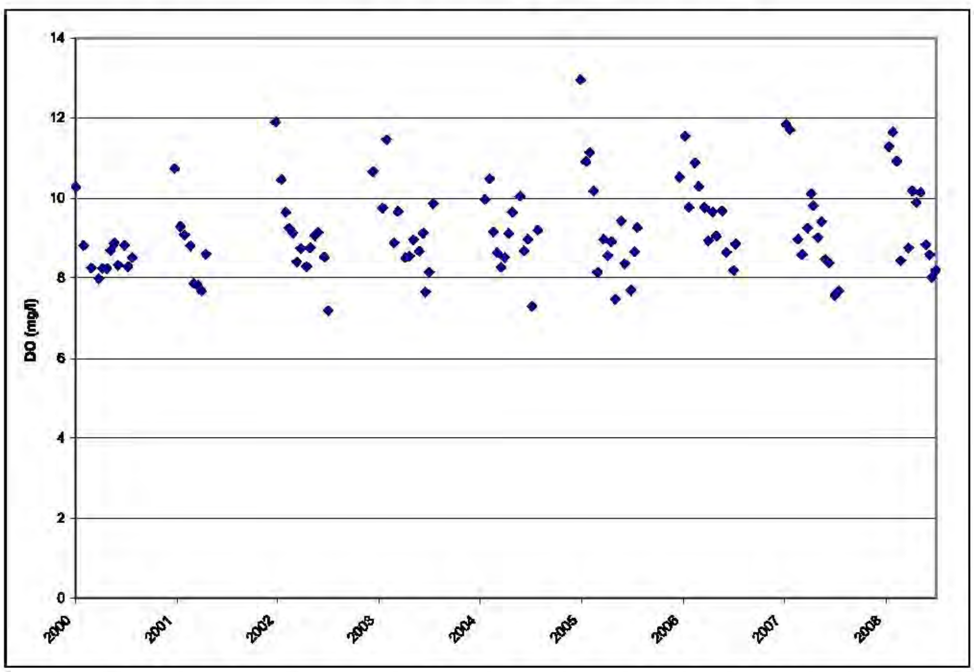

Figure A-10: Liberty Reservoir BCDPW Station NPA0059 Average Surface Dissolved Oxygen (2000-2008)

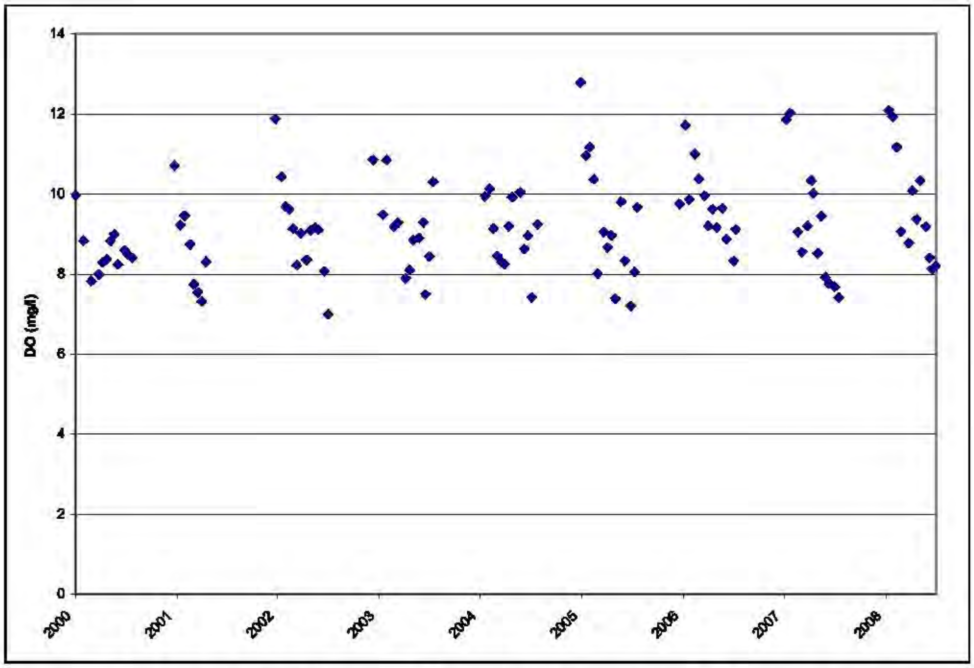

Figure A-11: Liberty Reservoir BCDPW Station NPA0067 Average Surface Dissolved Oxygen (2000-2008)

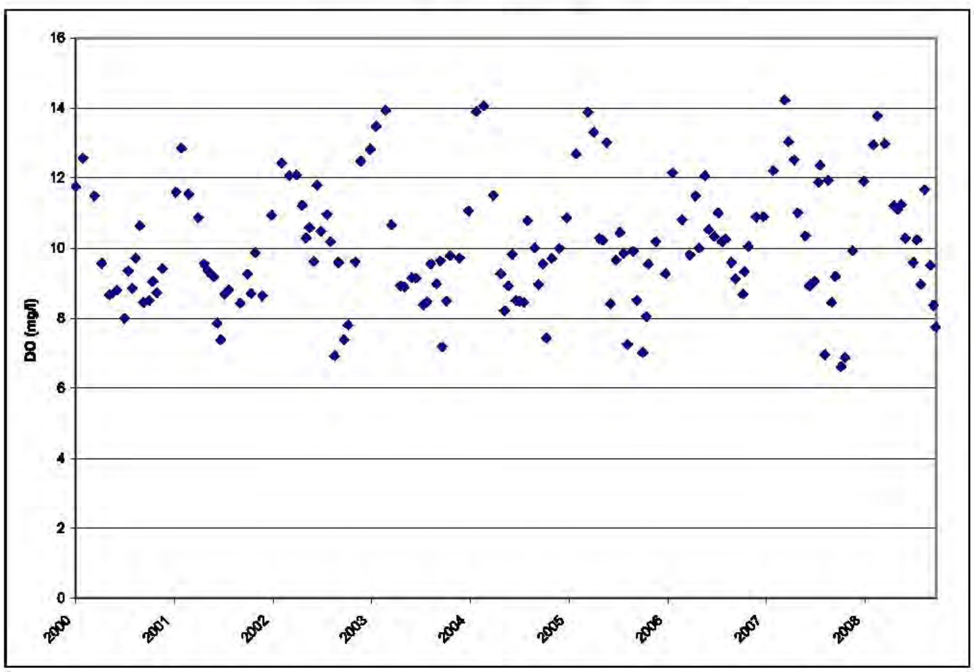

Figure A-12: Liberty Reservoir BCDPW Station NPA0105 Average Surface Dissolved Oxygen (2000-2008)

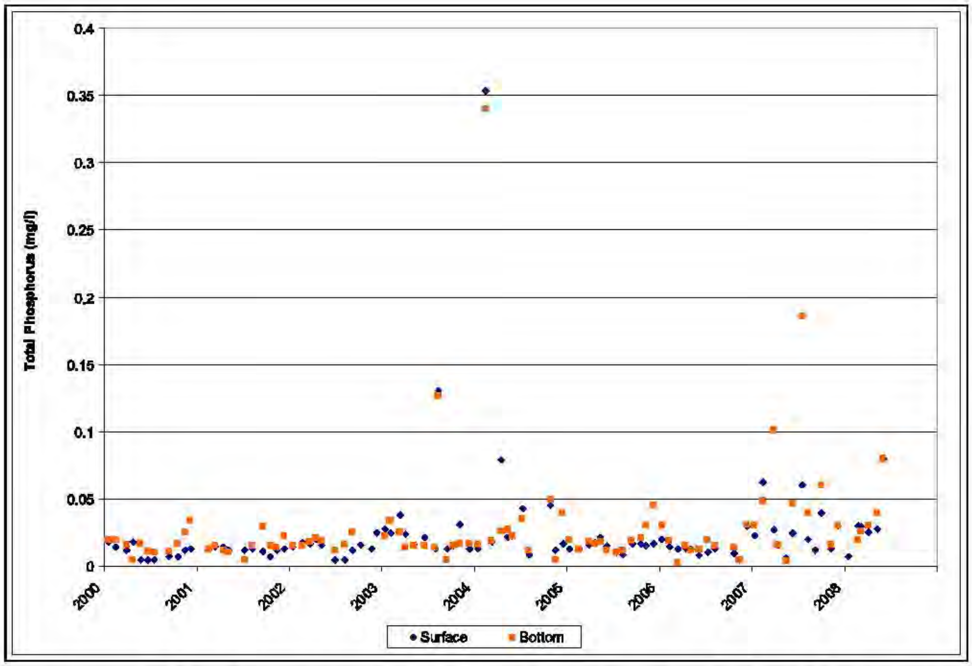

Figure A-13: Liberty Reservoir BCDPW Station NPA 0042 Average Total Phosphorus (2000-2008)

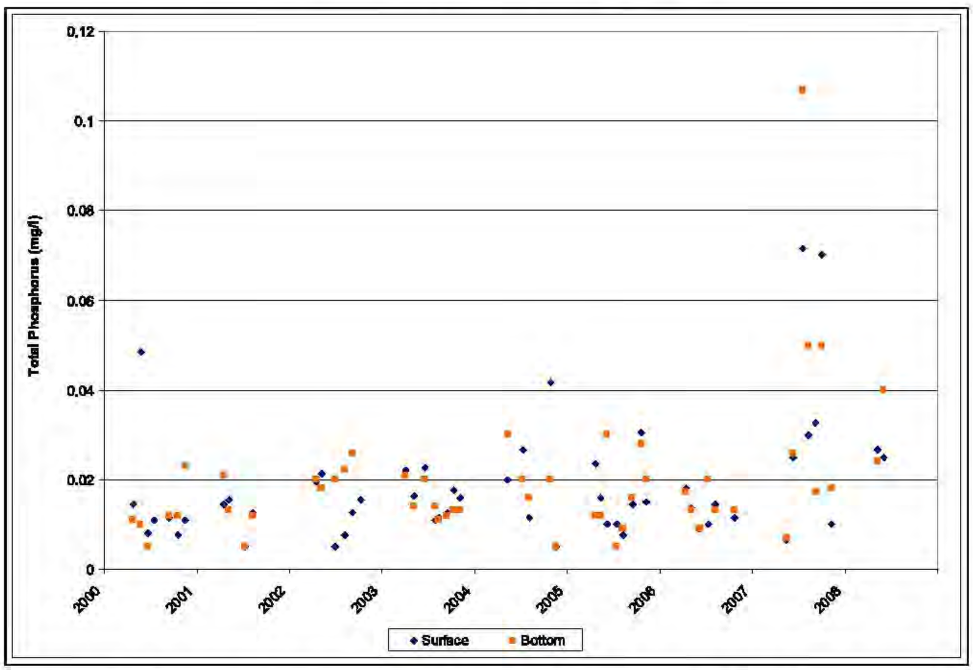

Figure A-14: Liberty Reservoir BCDPW Station NPA0059 Average Total Phosphorus (2000-2008)

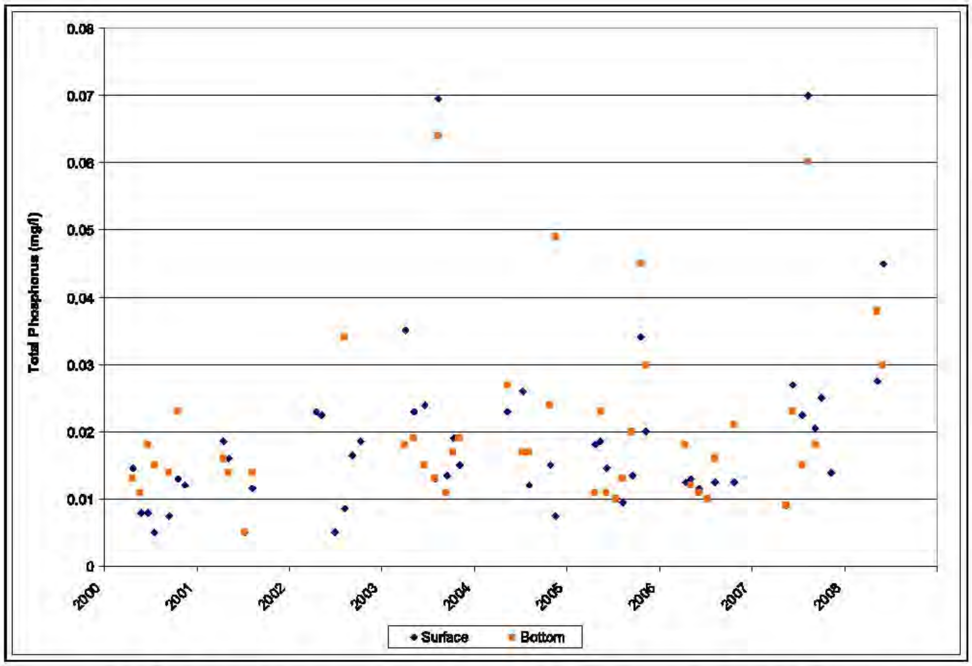

Figure A-15: Liberty Reservoir BCDPW Station NPA0067 Average Total Phosphorus (2000-2008)

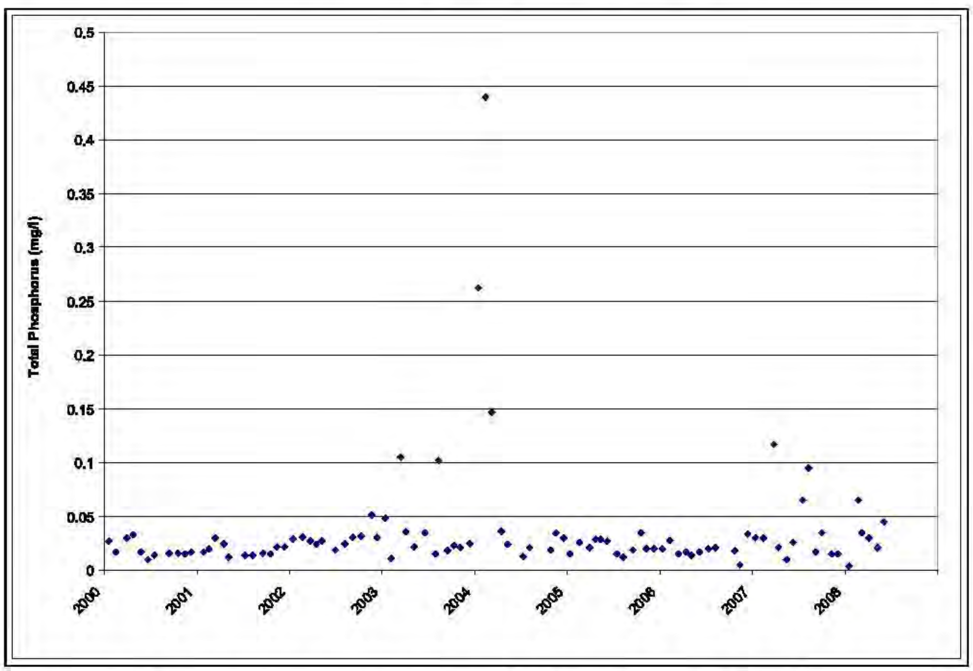

Figure A-16: Liberty Reservoir BCDPW Station NPA0105 Average Total Phosphorus (2000-2008)

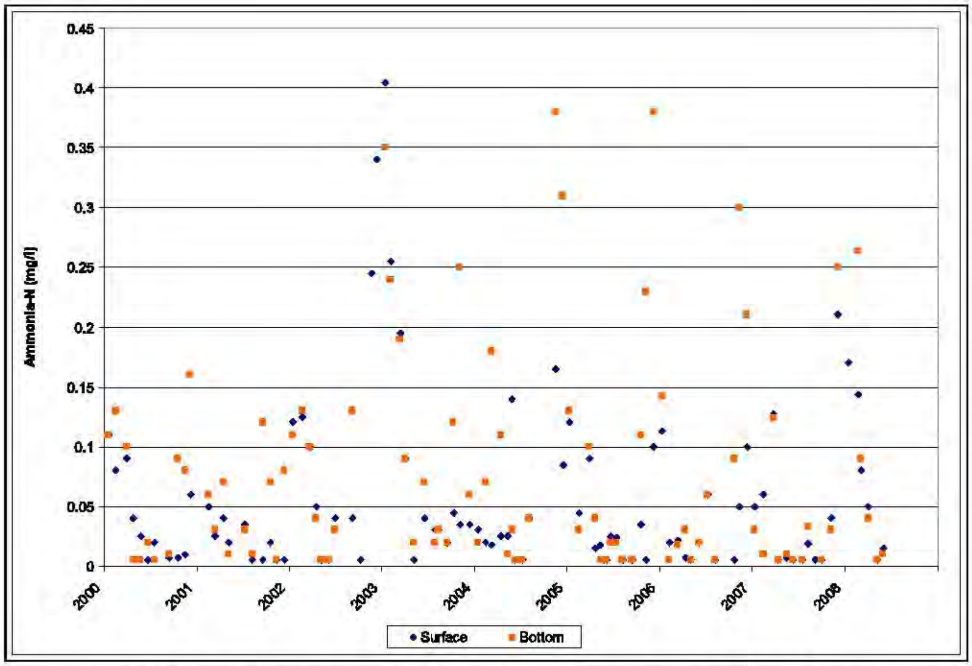

Figure A-17: Liberty Reservoir BCDPW Station NPA0042 Average Ammonia (2000-2008)

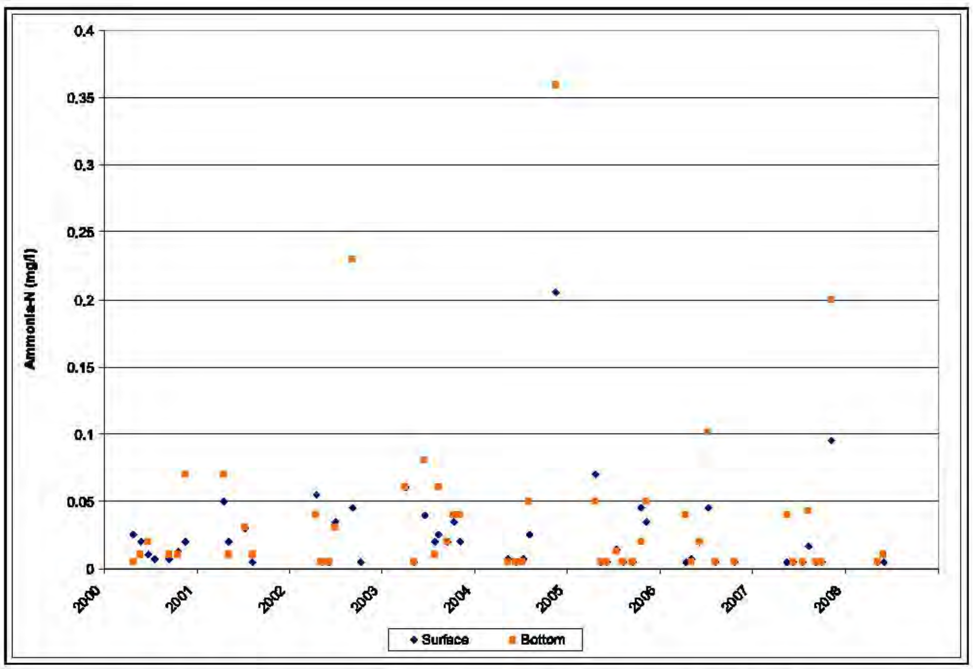

Figure A-18: Liberty Reservoir BCDPW Station NPA0059 Average Ammonia (2000-2008)

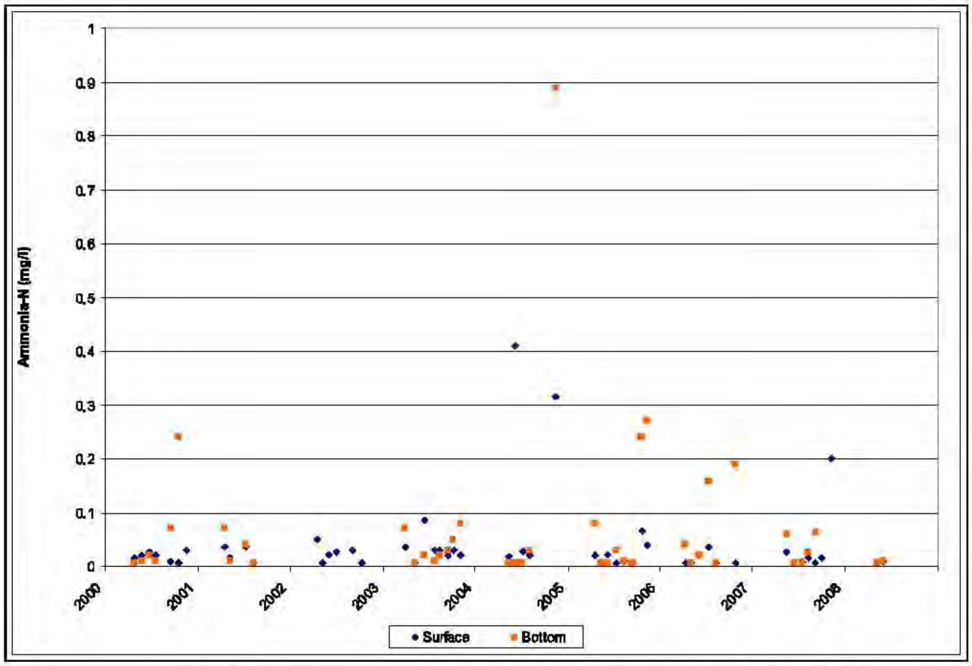

Figure A-19: Liberty Reservoir BCDPW Station NPA0067 Average Ammonia (2000-2008)

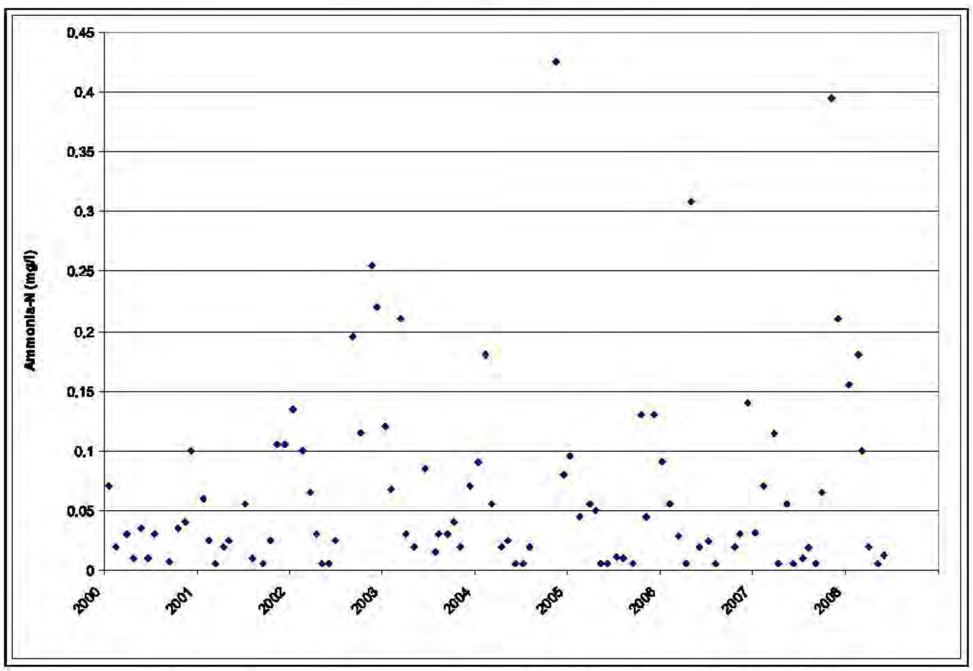

Figure A-20: Liberty Reservoir BCDPW Station NPA0105 Average Ammonia (2000-2008)

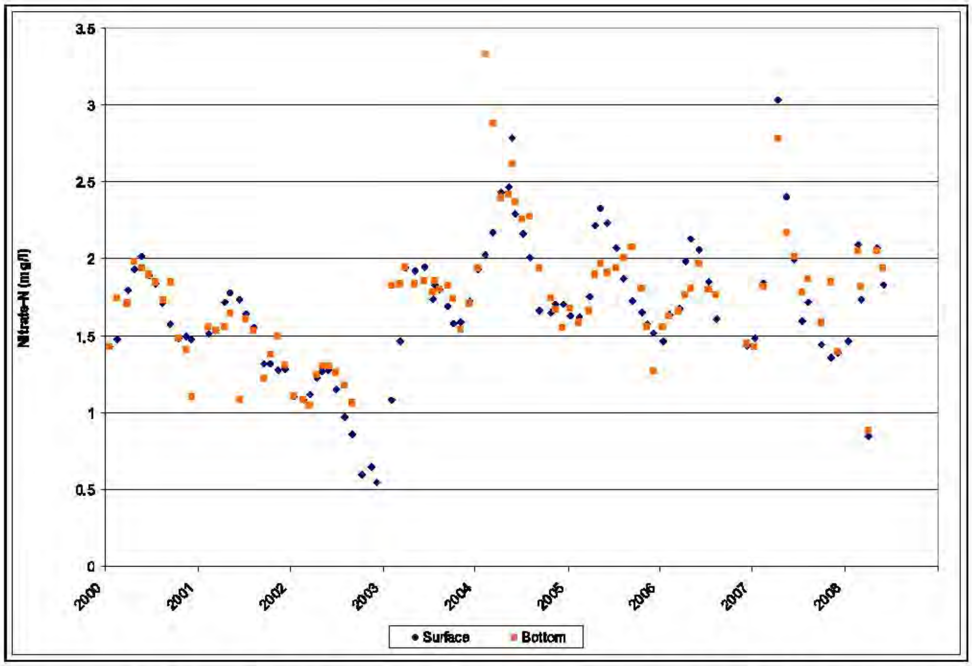

Figure A-21: Liberty Reservoir BCDPW Station NPA0042 Average Nitrate (2000-2008)

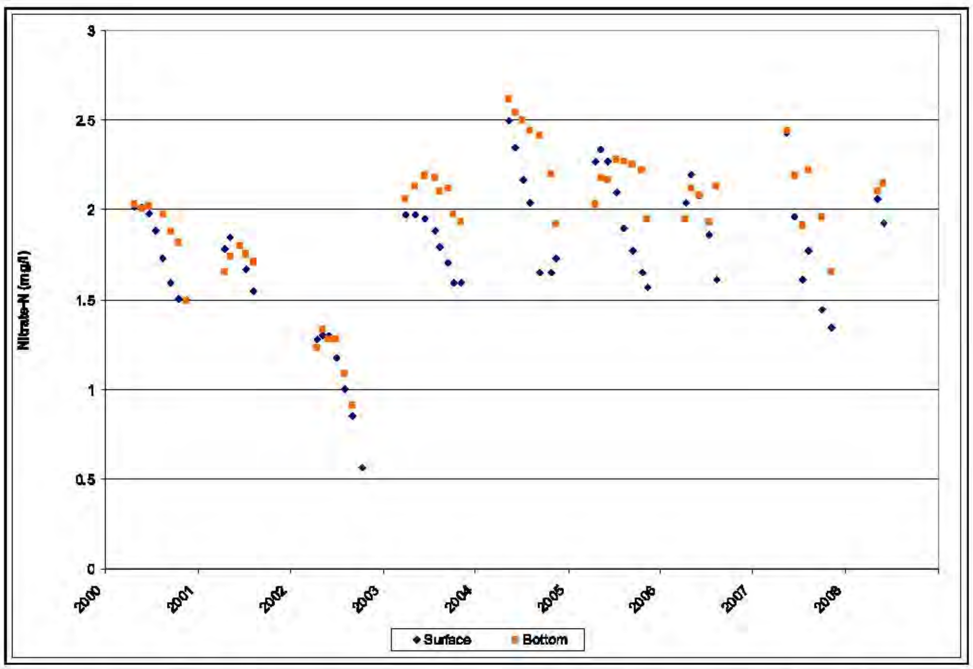

Figure A-22: Liberty Reservoir BCDPW Station NPA0059 Average Nitrate (2000-2008)

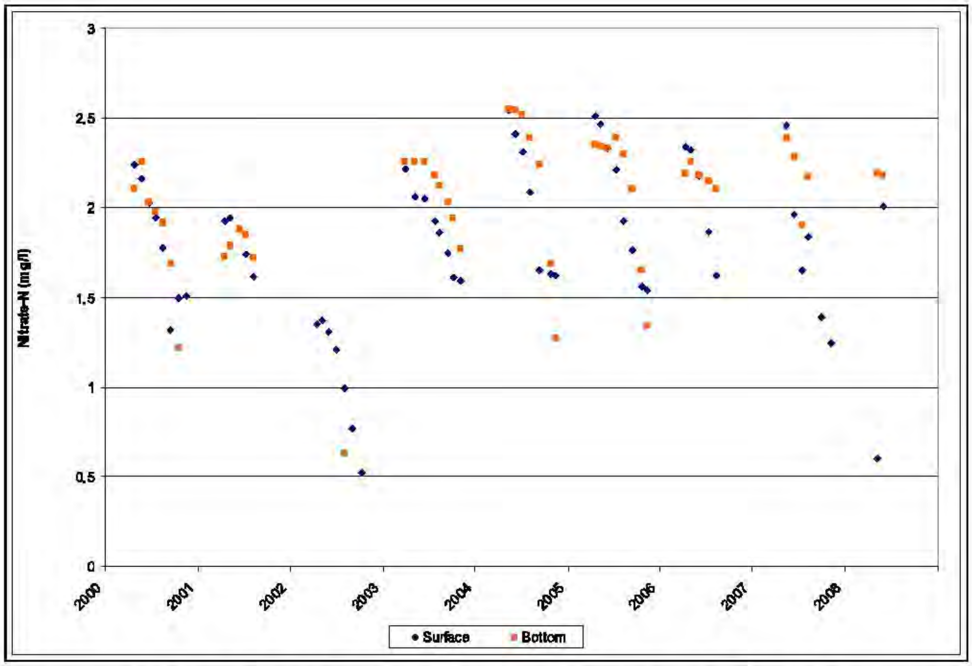

Figure A-23: Liberty Reservoir BCDPW Station NPA0067 Average Nitrate (2000-2008)

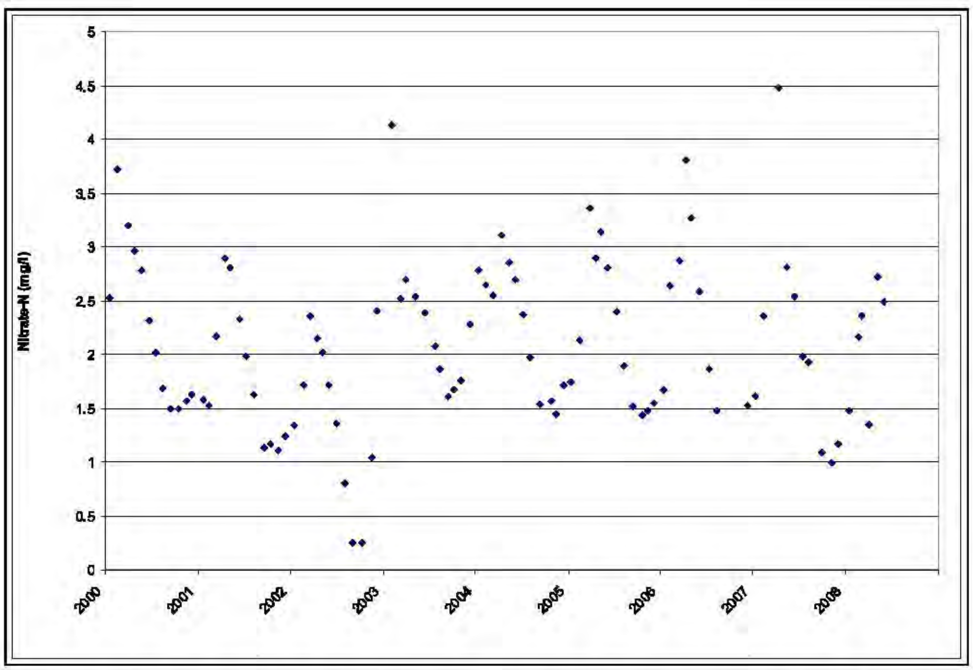

Figure A-24: Liberty Reservoir BCDPW Station NPA0105 Average Nitrate (2000-2008)

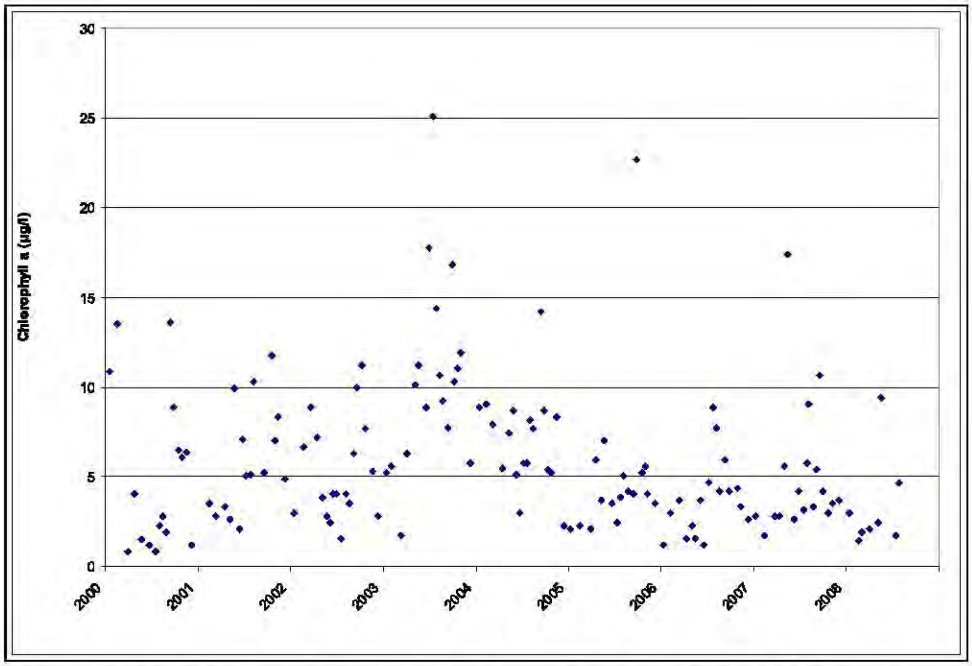

Figure A-25: Liberty Reservoir BCDPW Station NPA0042 Maximum Surface Chlorophyll a (2000-2008)

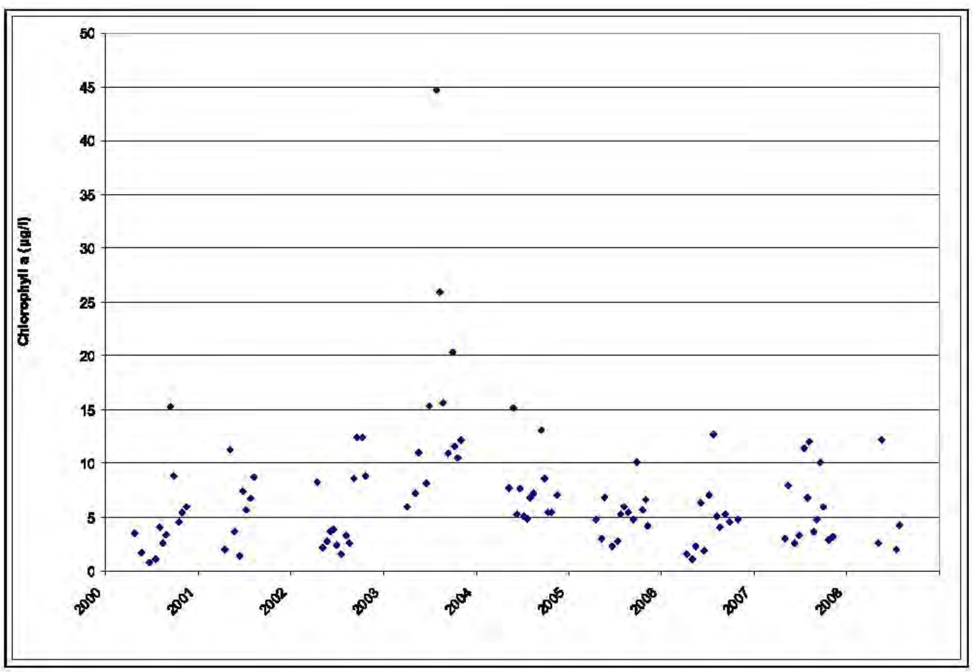

Figure A-26: Liberty Reservoir BCDPW Station NPA0059 Maximum Surface Chlorophyll a (2000-2008)

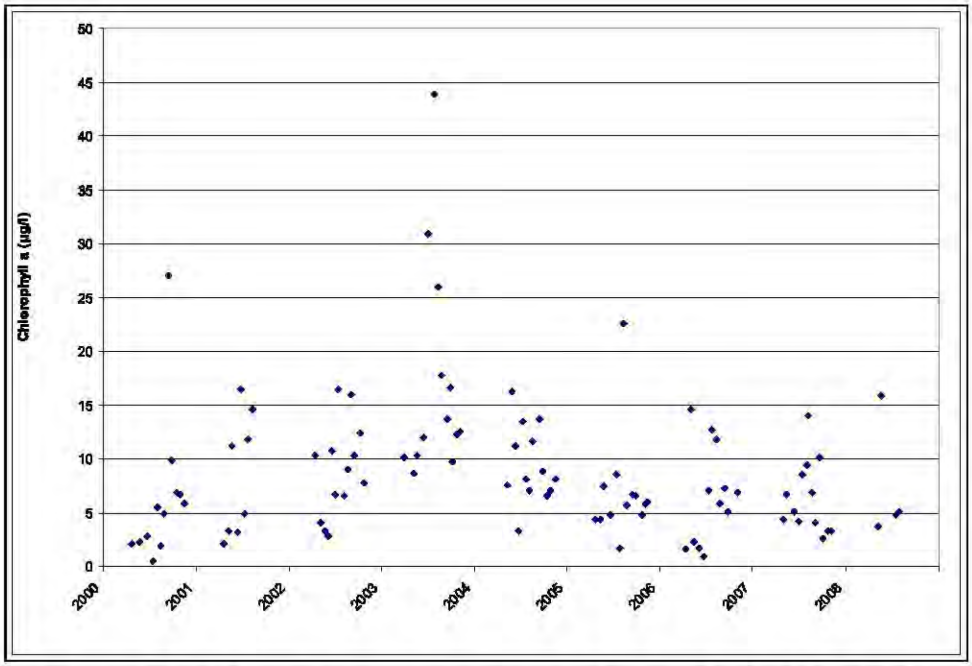

Figure A-27: Liberty Reservoir BCDPW Station NPA0067 Maximum Surface Chlorophyll a- (2000-2008)

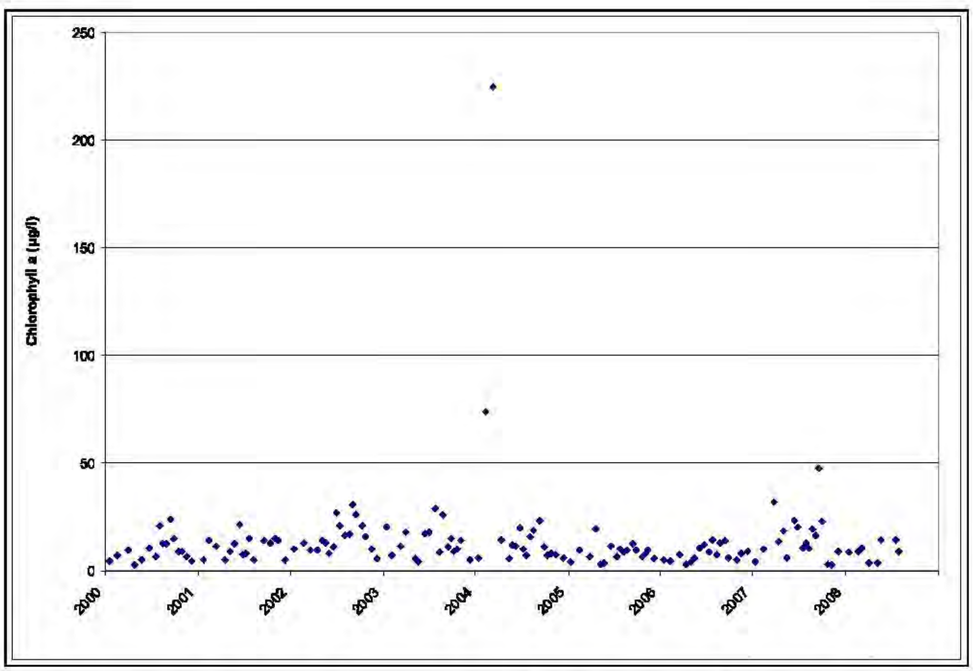

Figure A-28: Liberty Reservoir BCDPW Station NPA0105 Maximum Surface Chlorophyll a- (2000-2008)

Table A-1: Liberty Reservoir Maximum Chla Concentrations by Month and Year

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	10.85	13.47	9.38	4.02	5.07	10.29	20.66	13.74	27.05	9.03	6.49	5.42
2001	13.06	13.99	11.26	4.94	12.45	21.26	17.79	14.55	13.85	14.74	13.65	4.89
2002	10.12	13.43	9.57	10.29	13.62	15.54	26.81	24.39	30.65	20.7	10.12	5.6
2003	20.29	7.03	11.58	17.58	11.21	30.86	44.63	25.98	20.27	12.32	13.65	5.78
2004	8.85	73.95	224.87	14.21	16.19	19.92	13.44	18.83	23.2	7.75	8.31	5.78
2005	4.18	9.2	6.67	19.11	7.39	11.39	10.66	22.61	22.69	7.84	9.38	5.44
2006	4.72	5.96	7.21	3.13	17.39	11.76	14.18	13.06	13.83	6.85	7.93	9.02
2007	4.01	9.93	31.68	13.24	18.34	23.05	16.47	19.5	75.56	26.18	3.66	9.02
2008	8.43	9	10.2	3.66	15.87		14.38					

Appendix B

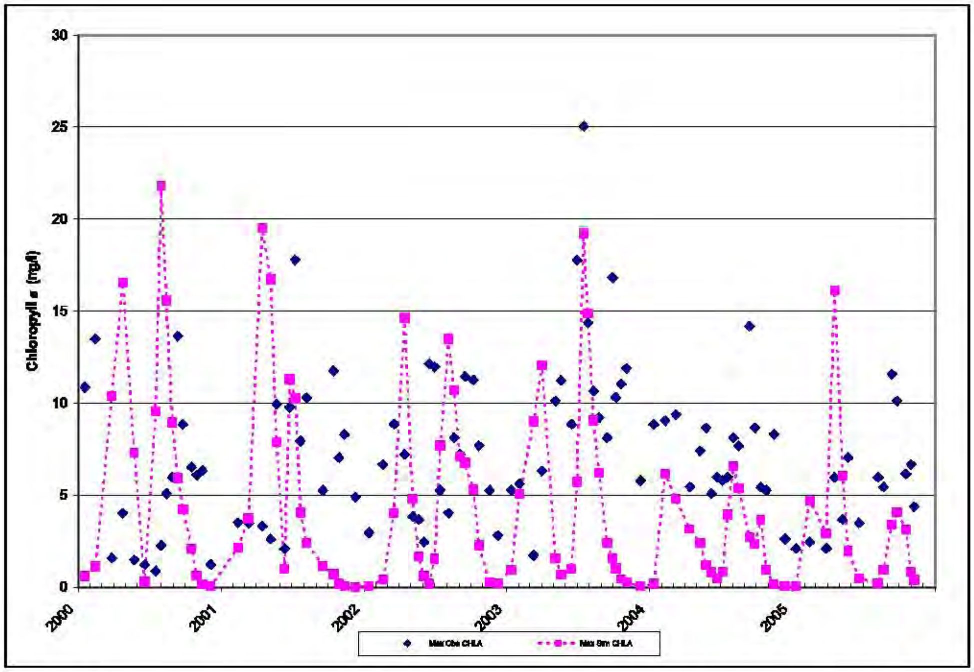

Figure B-1: Liberty Reservoir BCDPW Station NPA042 Observed and Simulated (Calibration Scenario) Maximum Chla Concentrations on Sampling Dates

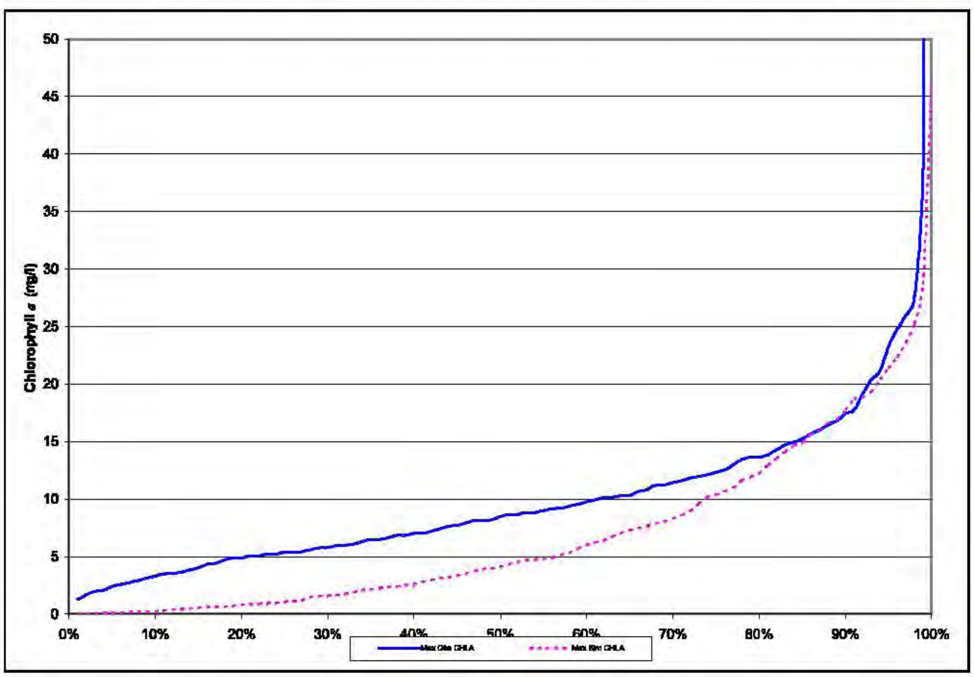

Figure B-2: Liberty Reservoir Observed and Simulated (Calibration Scenario) Cumulative Distribution of Chla Concentrations on Sampling Dates

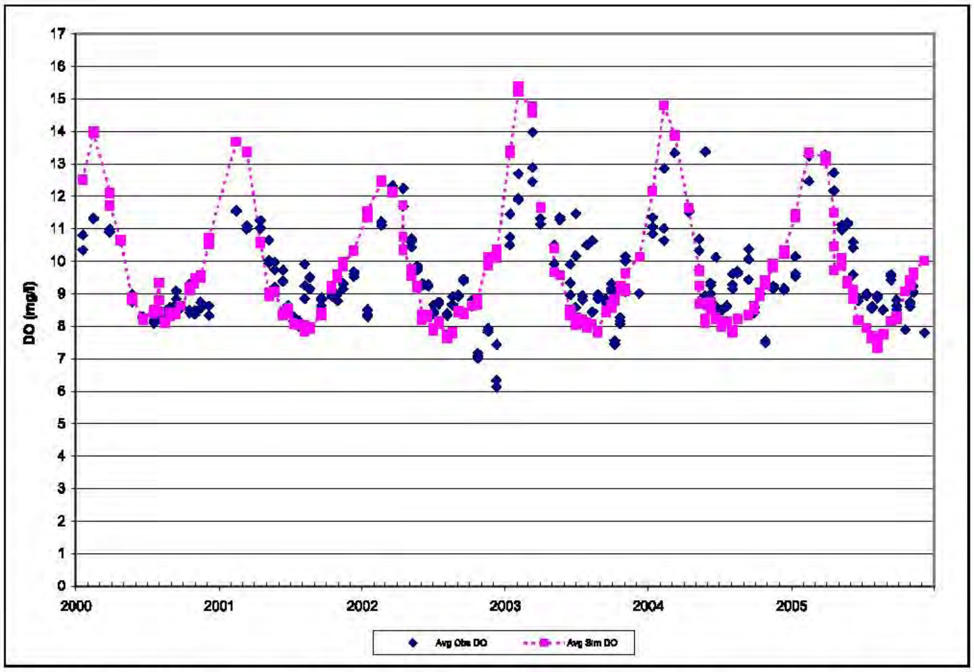

Figure B-3: Liberty Reservoir BCDPW Station NPA042 Observed and Simulated (Calibration Scenario) Average Surface DO Concentrations on Sampling Dates

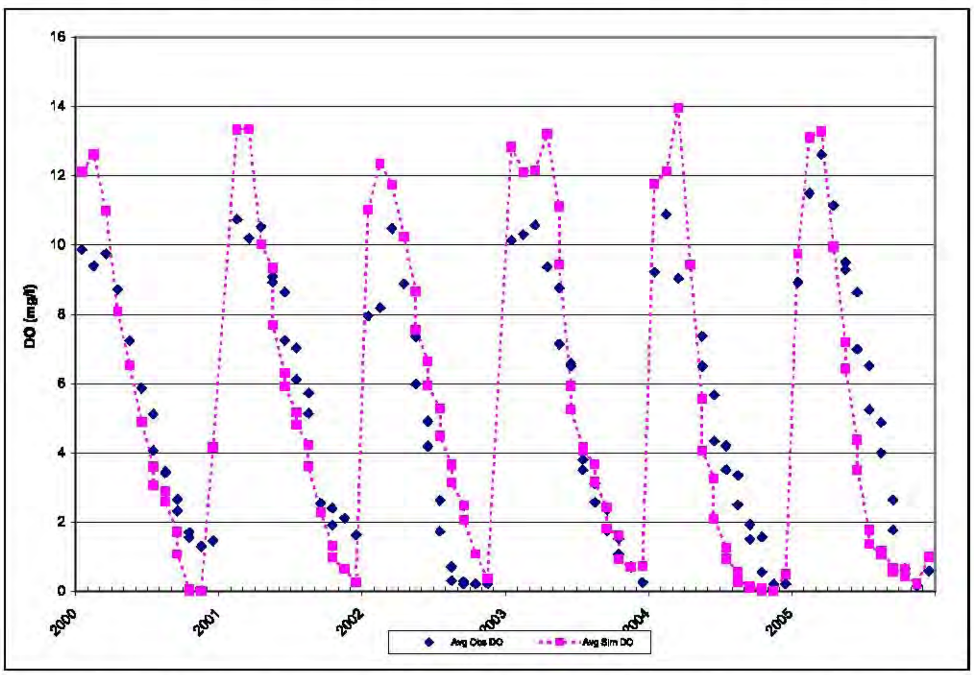

Figure B-4: Liberty Reservoir BCDPW Station NPA042 Observed and Simulated (Calibration Scenario) Average Bottom DO Concentrations on Sampling Dates

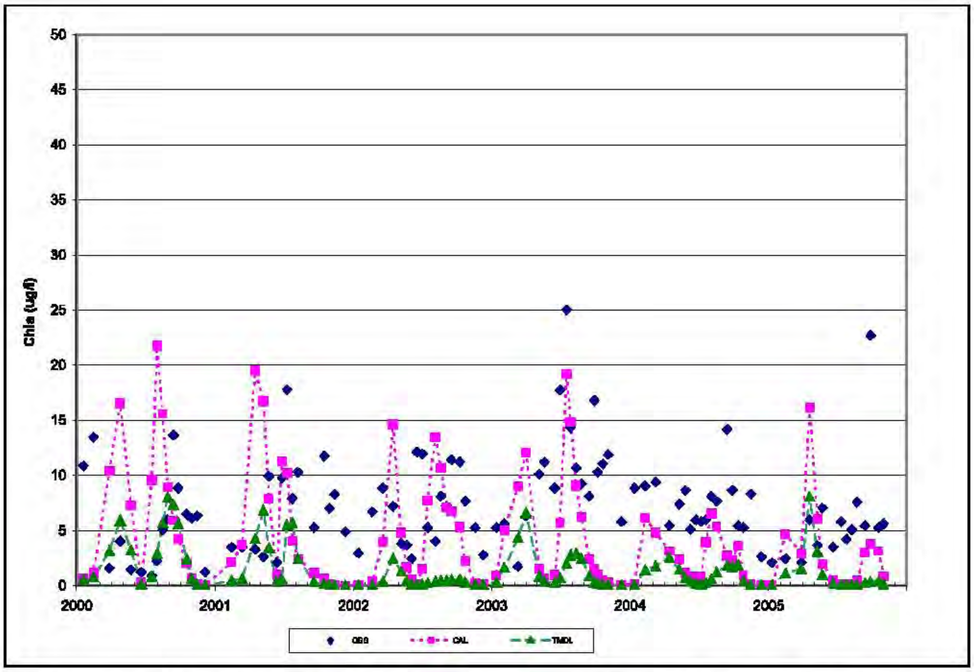

Figure B-5: Liberty Reservoir BCDPW Station NPA042 Observed and Simulated (Calibration and TMDL Scenarios) Maximum Chla Concentrations on Sampling Dates

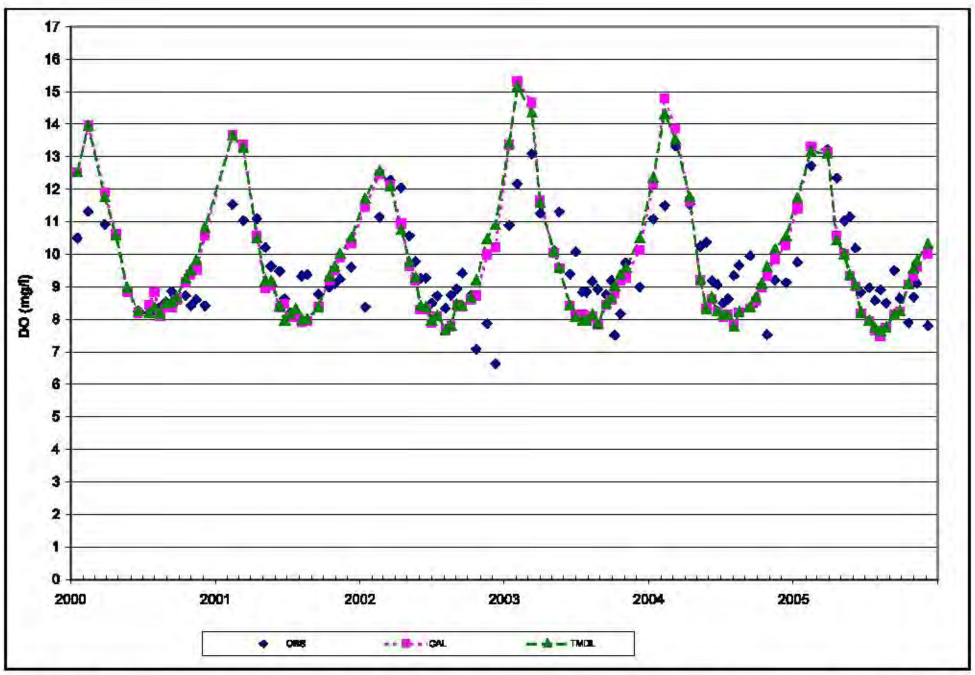

Figure B-6: Liberty Reservoir BCDPW Station NPA042 Observed and Simulated (Calibration and TMDL Scenarios) Average Surface DO Concentrations on Sampling Dates

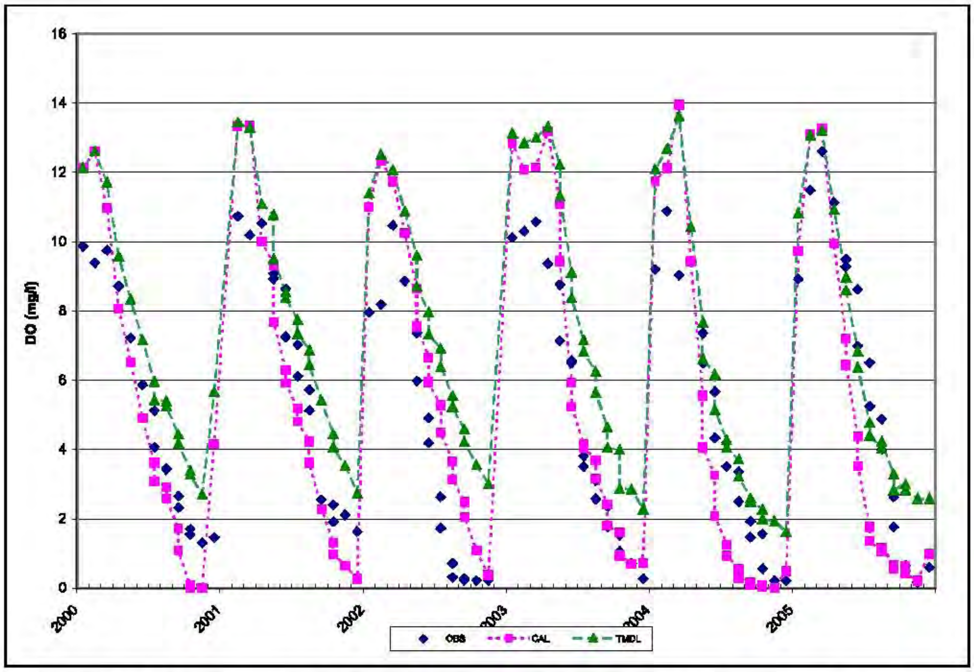

Figure B-7: Liberty Reservoir BCDPW Station NPA042 Observed and Simulated (Calibration and TMDL Scenarios) Average Bottom DO Concentrations on Sampling Dates

Appendix C

FINAL

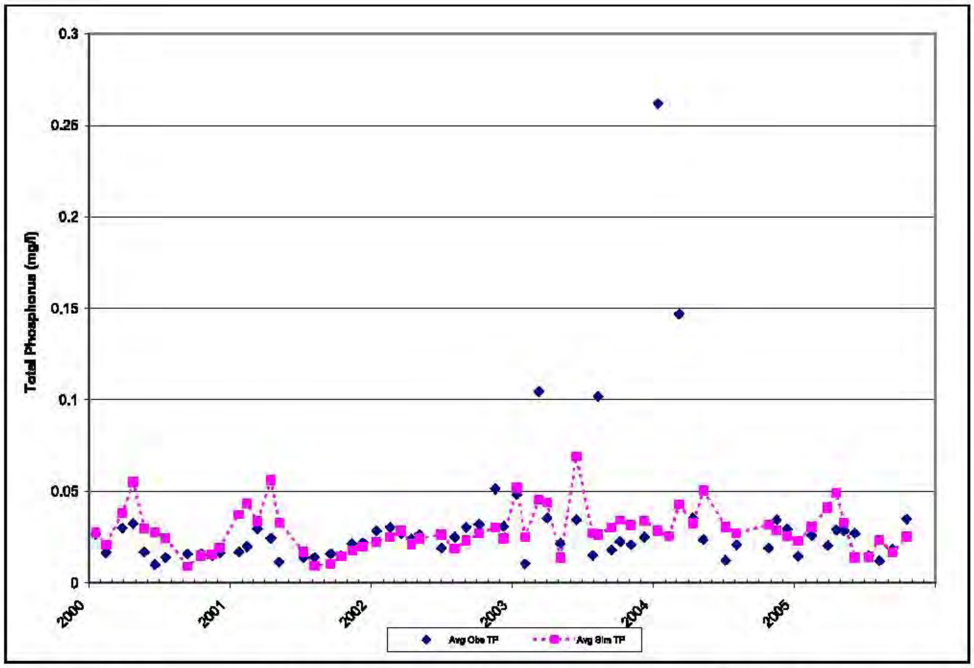

Figure C-1: Liberty Reservoir BCDPW Station NPA0105 Surface Observed and Simulated (Calibration) TP Concentrations on Sampling Dates

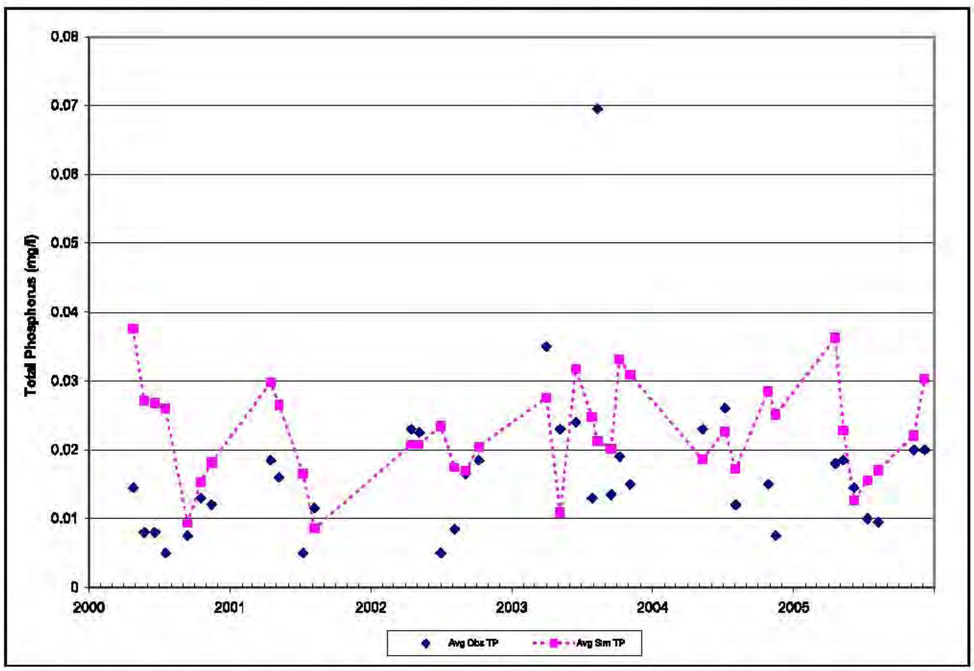

Figure C-2: Liberty Reservoir BCDPW Station NPA0067 Surface Observed and Simulated (Calibration) TP Concentrations on Sampling Dates

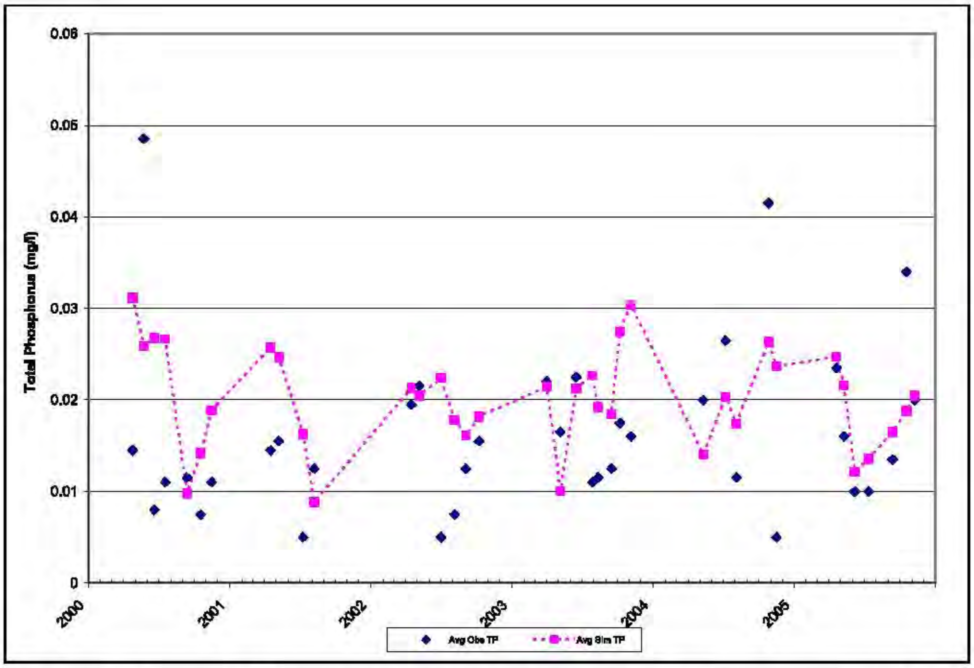

Figure C-3: Liberty Reservoir BCDPW Station NPA0059 Surface Observed and Simulated (Calibration) TP Concentrations on Sampling Dates

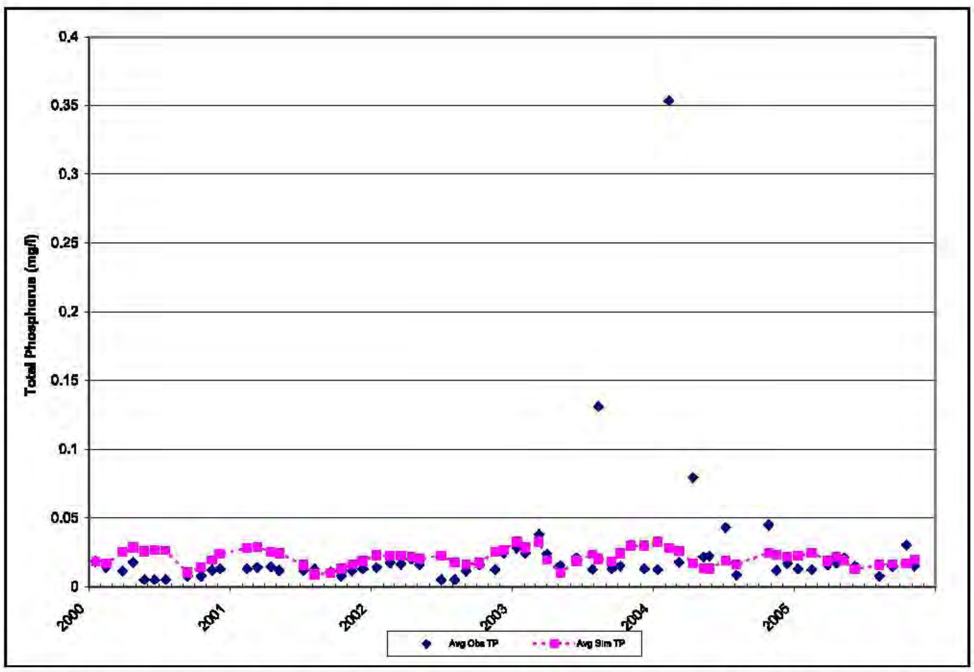

Figure C-4: Liberty Reservoir BCDPW Station NPA0042 Surface Observed and Simulated (Calibration) TP Concentrations on Sampling Dates

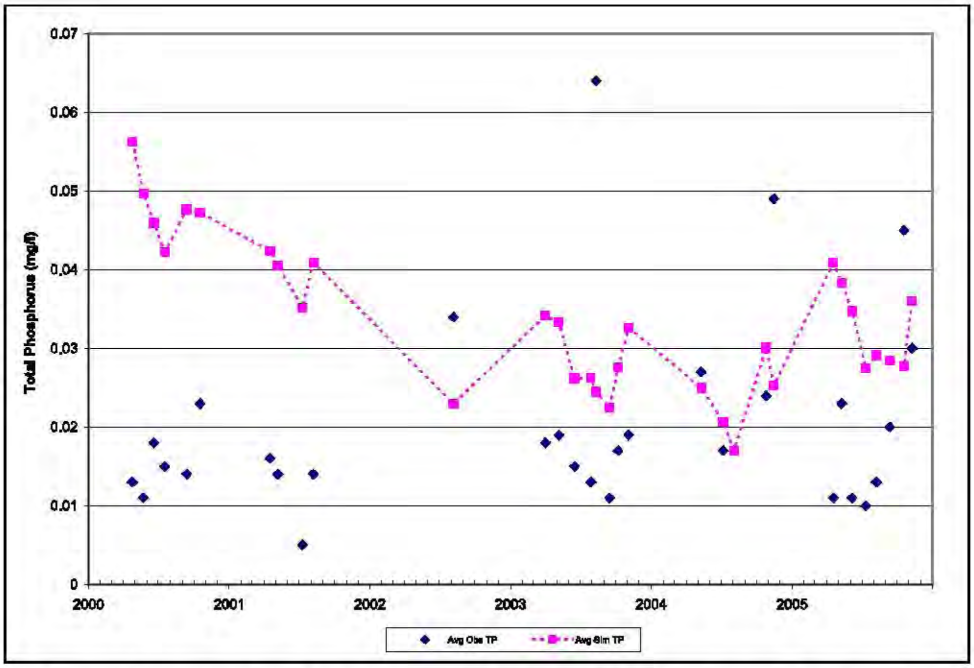

Figure C-5: Liberty Reservoir BCDPW Station NPA0067 Bottom Observed and Simulated (Calibration) TP Concentrations on Sampling Dates

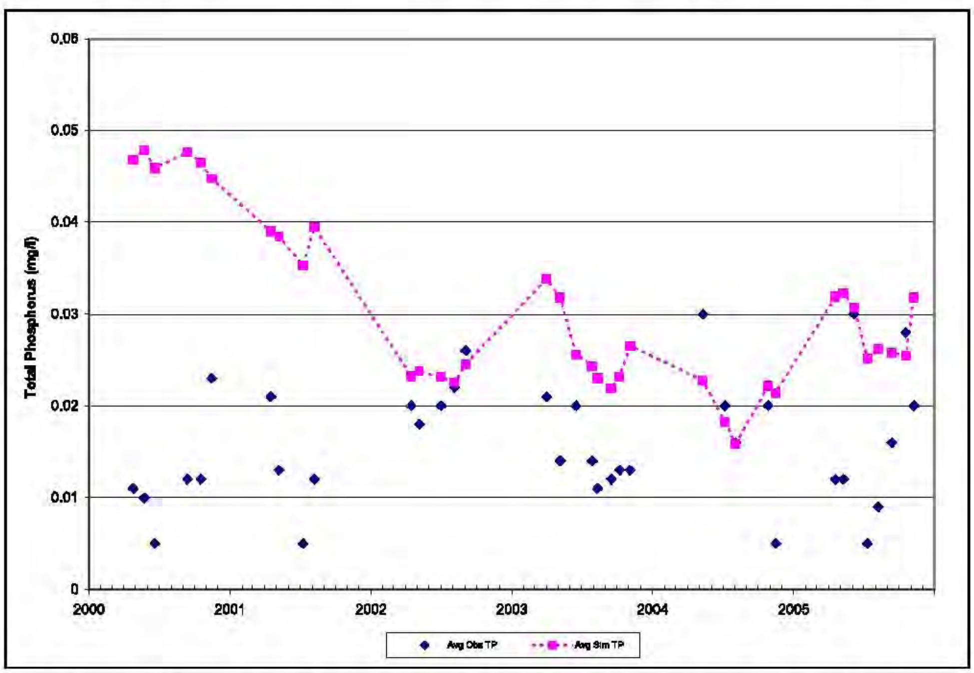

Figure C-6: Liberty Reservoir BCDPW Station NPA0059 Bottom Observed and Simulated (Calibration) TP Concentrations on Sampling Dates

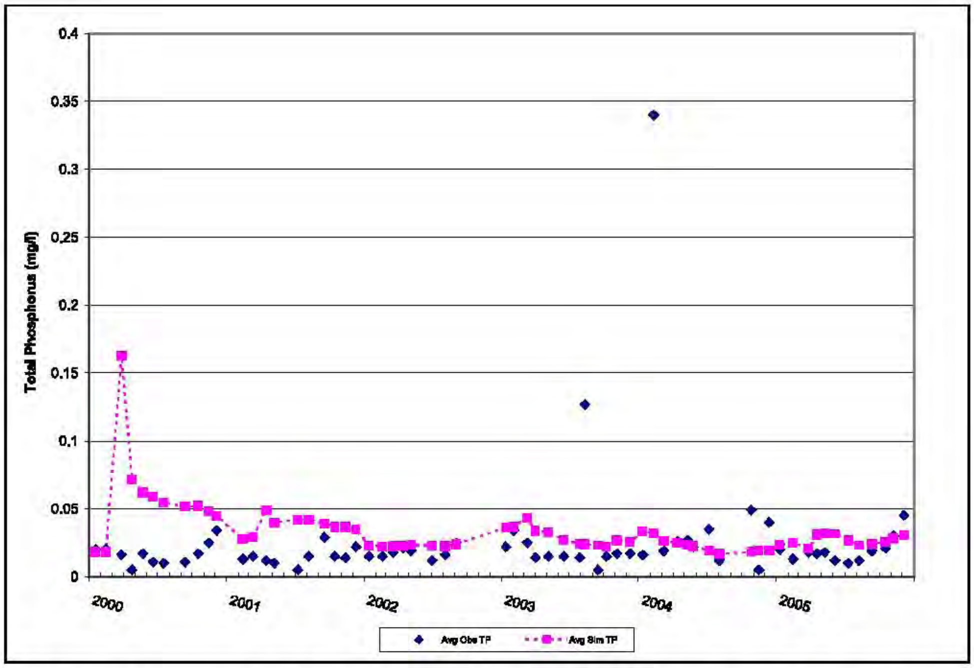

Figure C-7: Liberty Reservoir BCDPW Station NPA0042 Bottom Observed and Simulated (Calibration) TP Concentrations on Sampling Dates

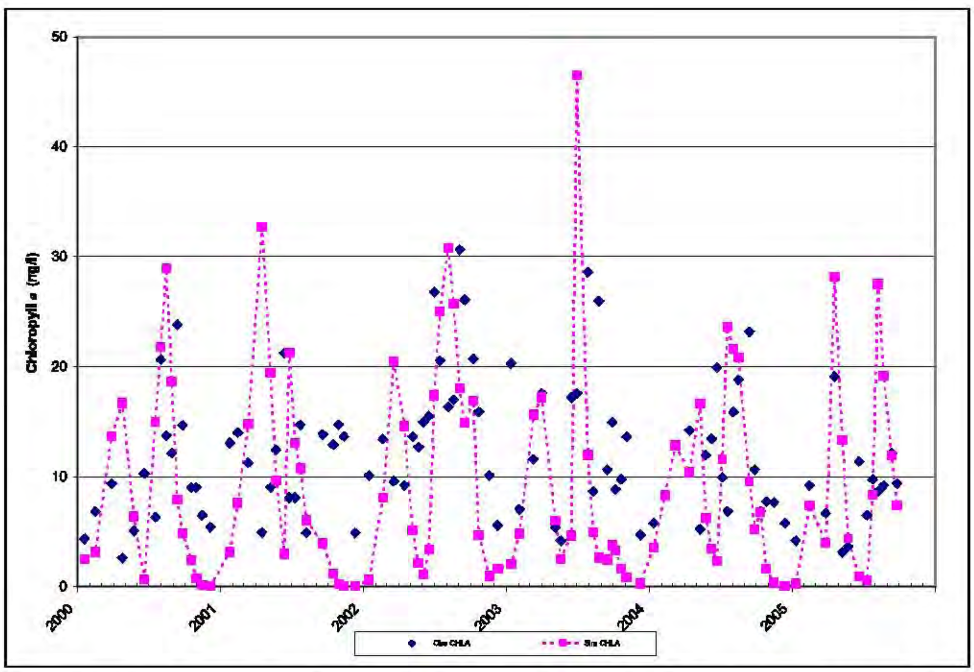

Figure C-8: Liberty Reservoir BCDPW Station NPA0105 Surface Observed and Simulated (Calibration) Chla Concentrations on Sampling Dates

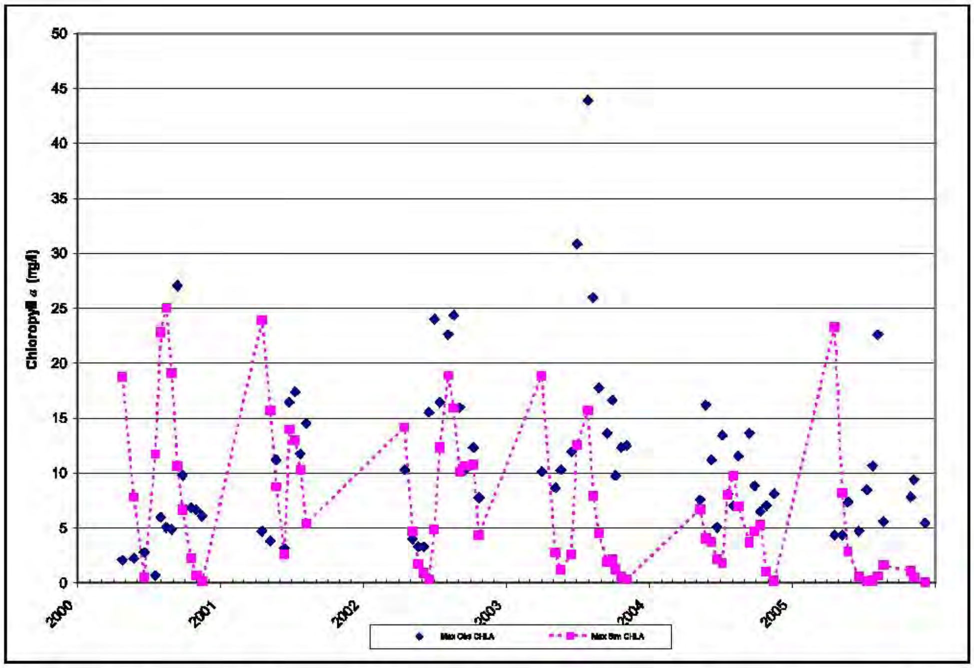

Figure C-9: Liberty Reservoir BCDPW Station NPA0067 Surface Observed and Simulated (Calibration) Chla Concentrations on Sampling Dates

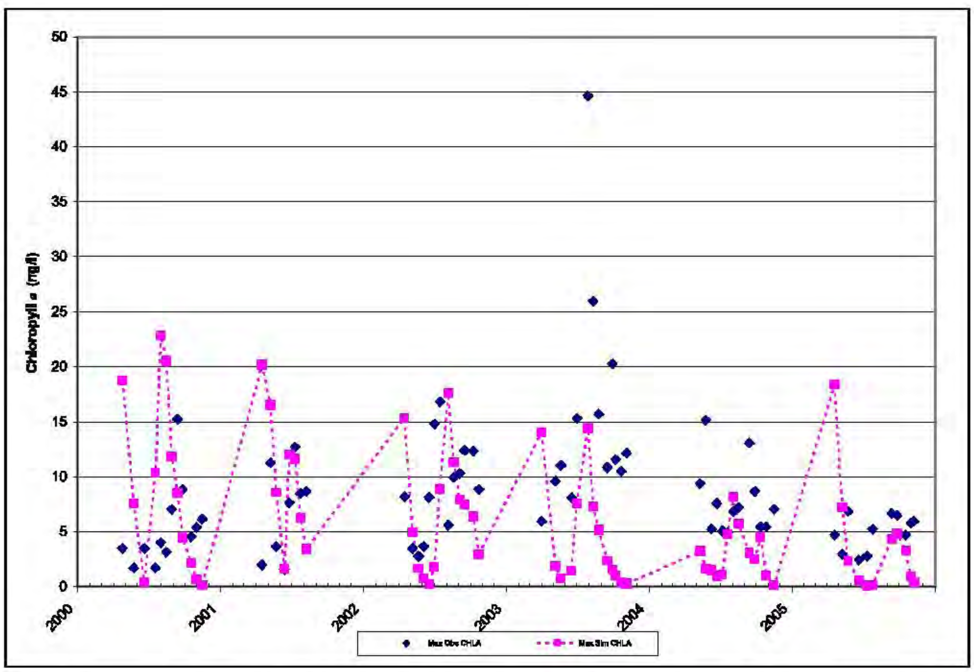

Figure C-10: Liberty Reservoir BCDPW Station NPA0059 Surface Observed and Simulated (Calibration) Chla Concentrations on Sampling Dates

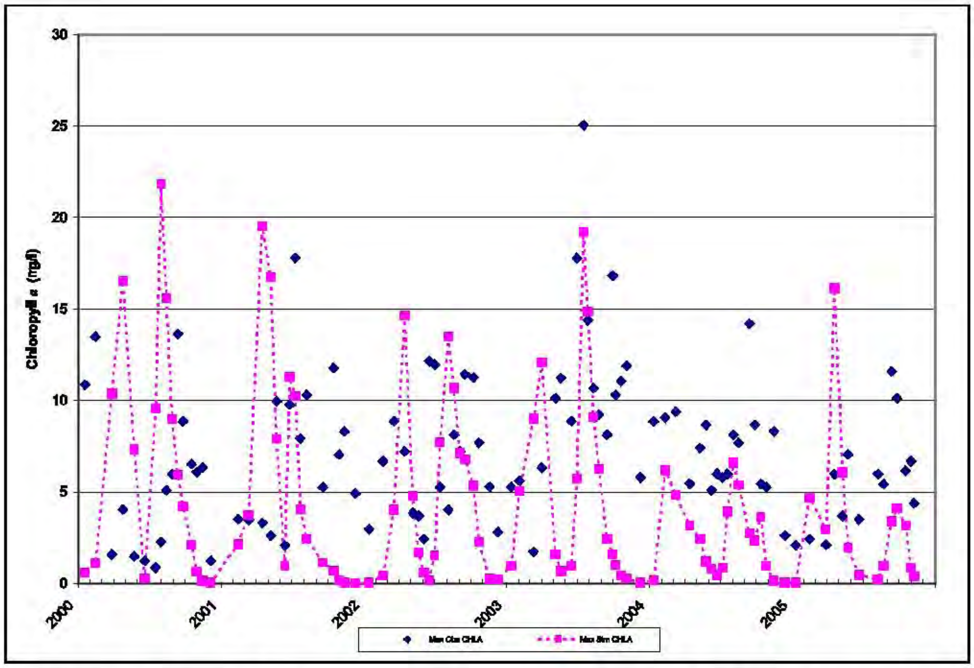

Figure C-11: Liberty Reservoir BCDPW Station NPA0042 Surface Observed and Simulated (Calibration) Chla Concentrations on Sampling Dates

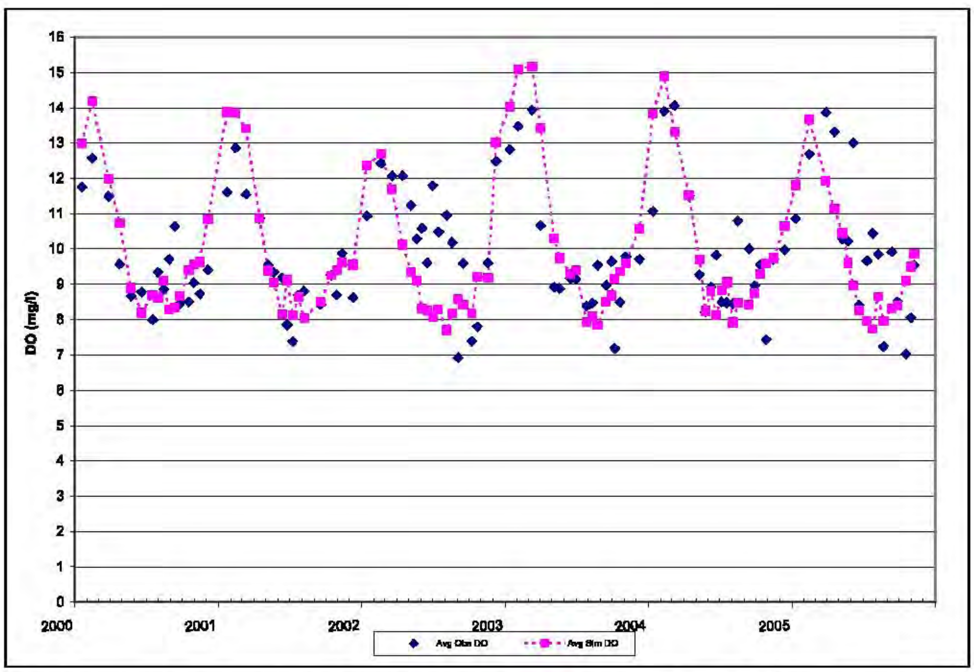

Figure C-12: Liberty Reservoir BCDPW Station NPA0105 Surface Observed and Simulated (Calibration) DO Concentrations on Sampling Dates

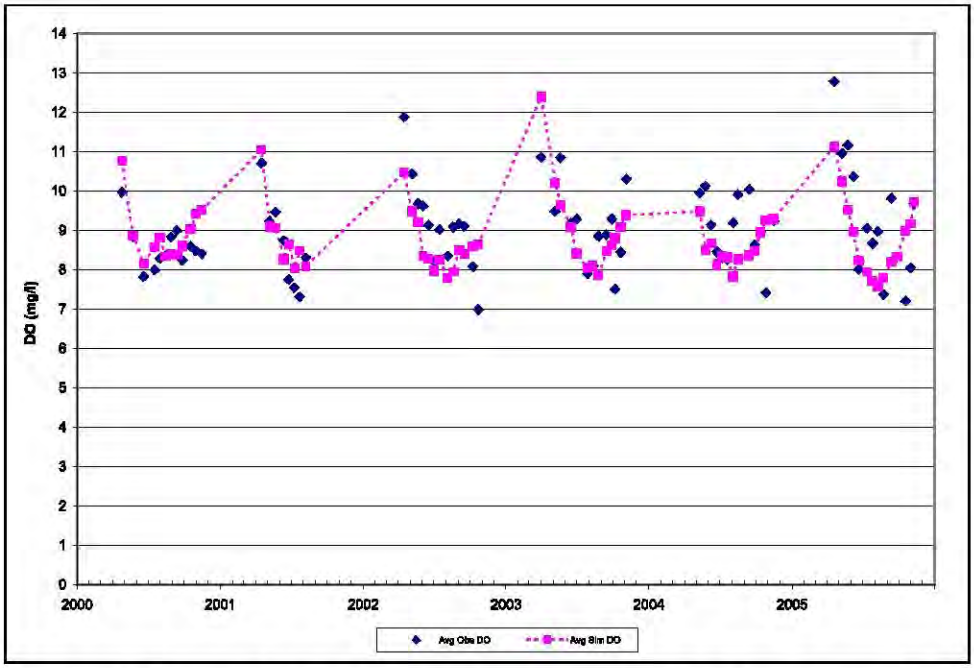

Figure C-13: Liberty Reservoir BCDPW Station NPA0067 Surface Observed and Simulated (Calibration) DO Concentrations on Sampling Dates

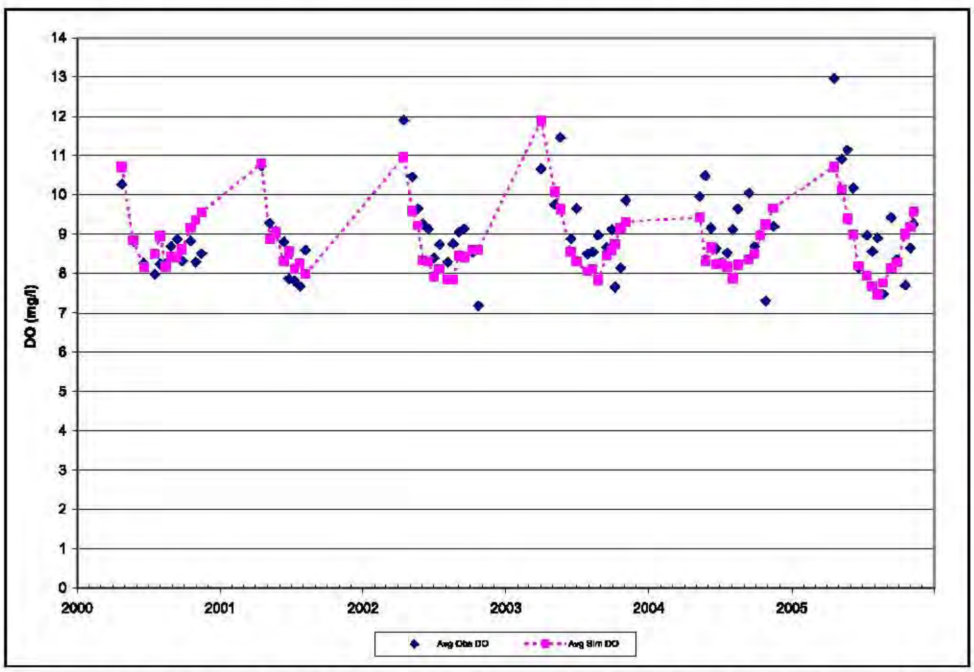

Figure C-14: Liberty Reservoir BCDPW Station NPA0059 Surface Observed and Simulated (Calibration) DO Concentrations on Sampling Dates

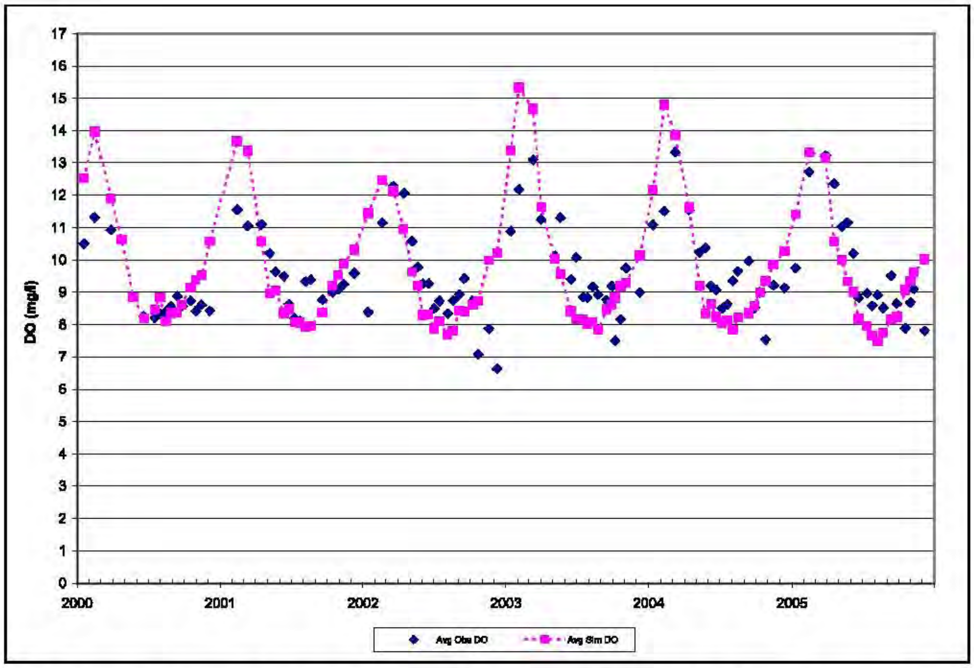

Figure C-15: Liberty Reservoir BCDPW Station NPA0042 Surface Observed and Simulated (Calibration) DO Concentrations on Sampling Dates

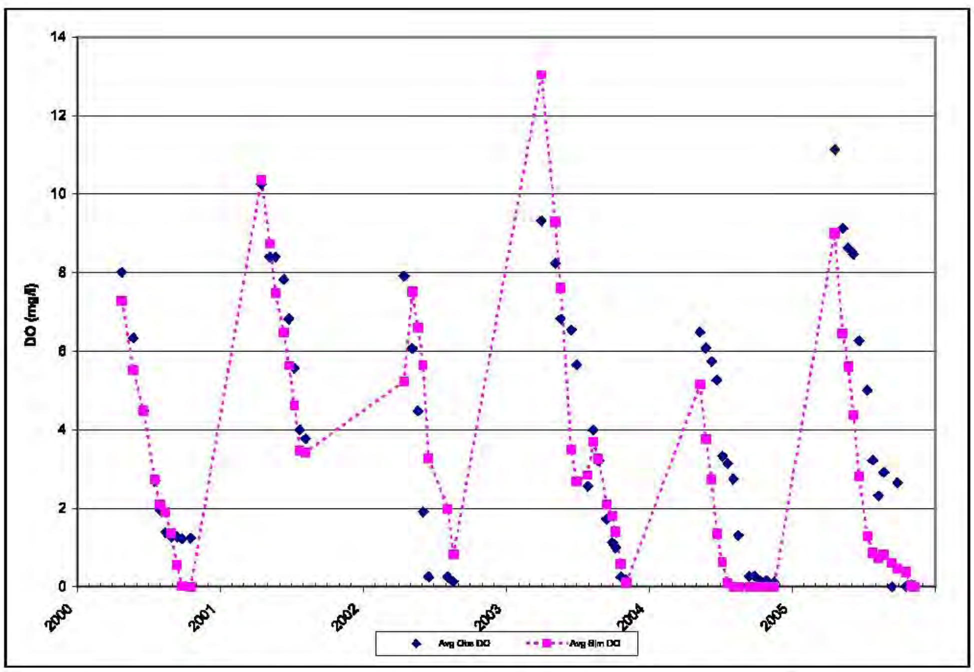

Figure C-16: Liberty Reservoir BCDPW Station NPA0067 Bottom Observed and Simulated (Calibration) DO Concentrations on Sampling Dates

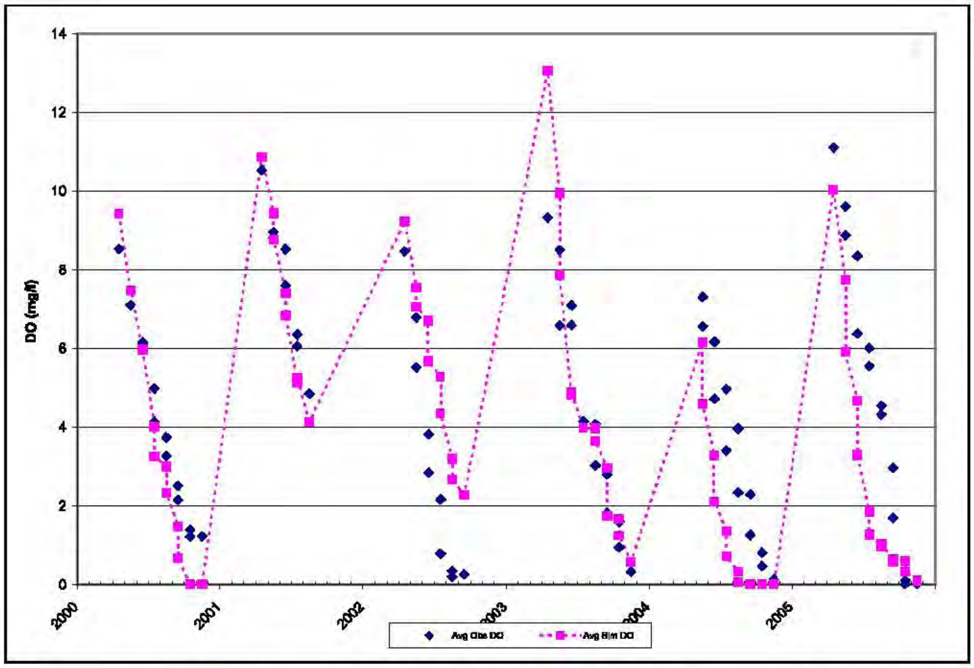

Figure C-17: Liberty Reservoir BCDPW Station NPA0059 Bottom Observed and Simulated (Calibration) DO Concentrations on Sampling Dates

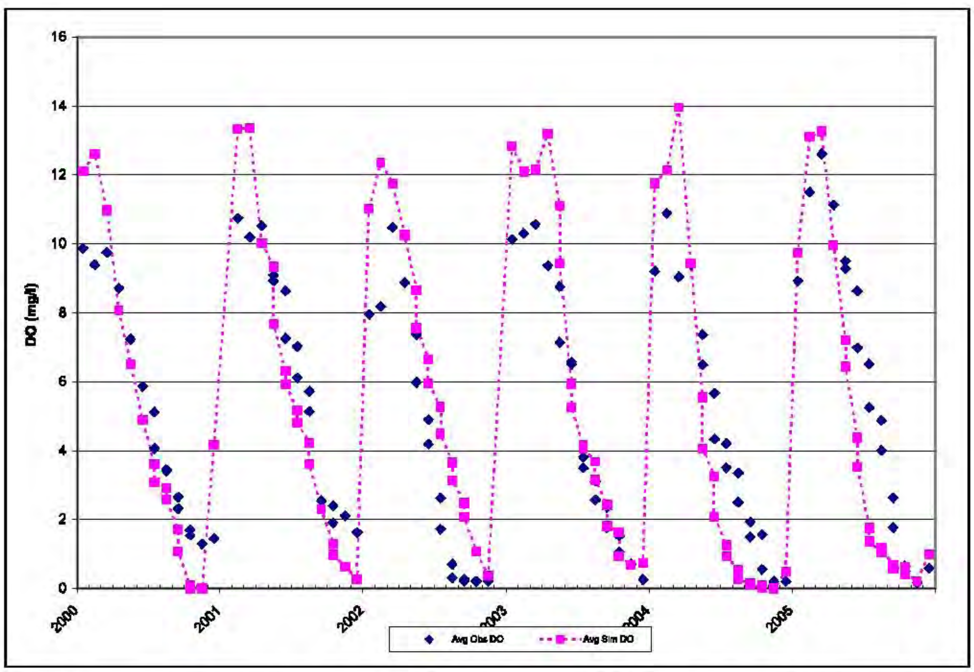

Figure C-18: Liberty Reservoir BCDPW Station NPA0042 Bottom Observed and Simulated (Calibration) DO Concentrations on Sampling Dates

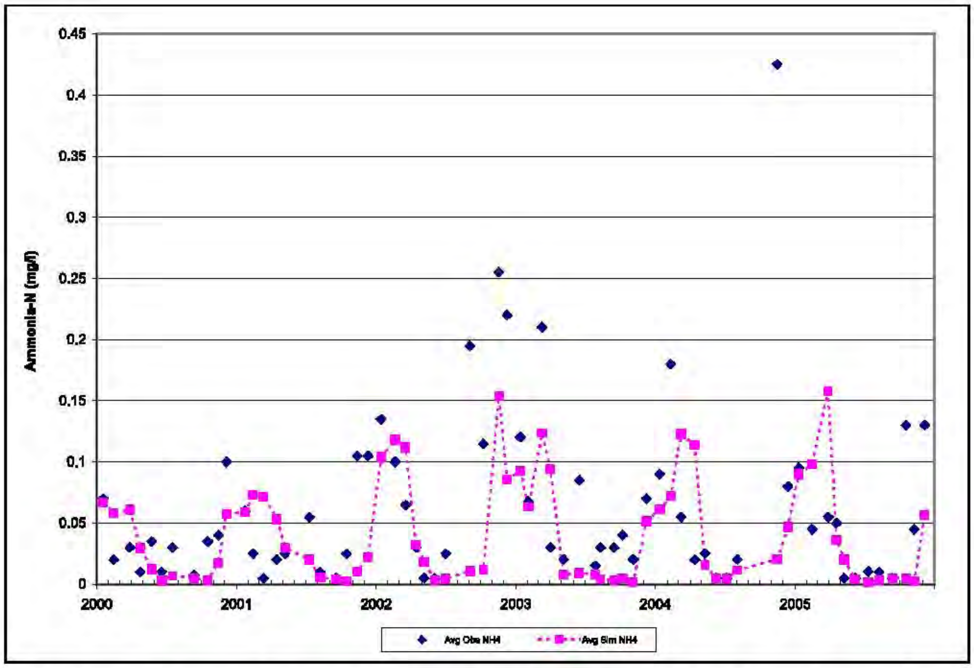

Figure C-19: Liberty Reservoir BCDPW Station NPA0105 Surface Observed and Simulated (Calibration) NH4 Concentrations on Sampling Dates

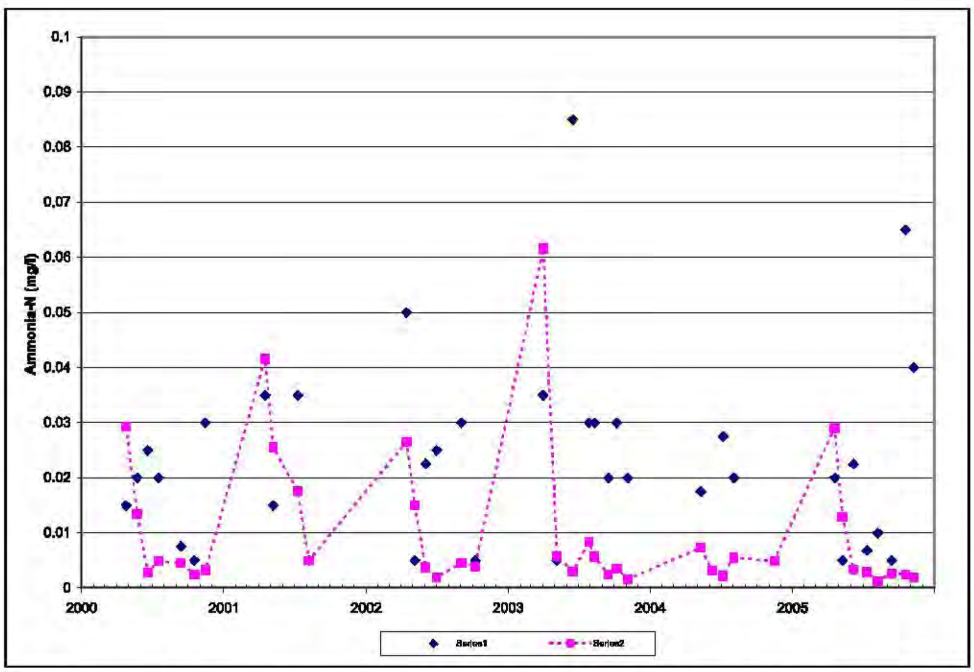

Figure C-20: Liberty Reservoir BCDPW Station NPA0067 Surface Observed and Simulated (Calibration) NH4 Concentrations on Sampling Dates

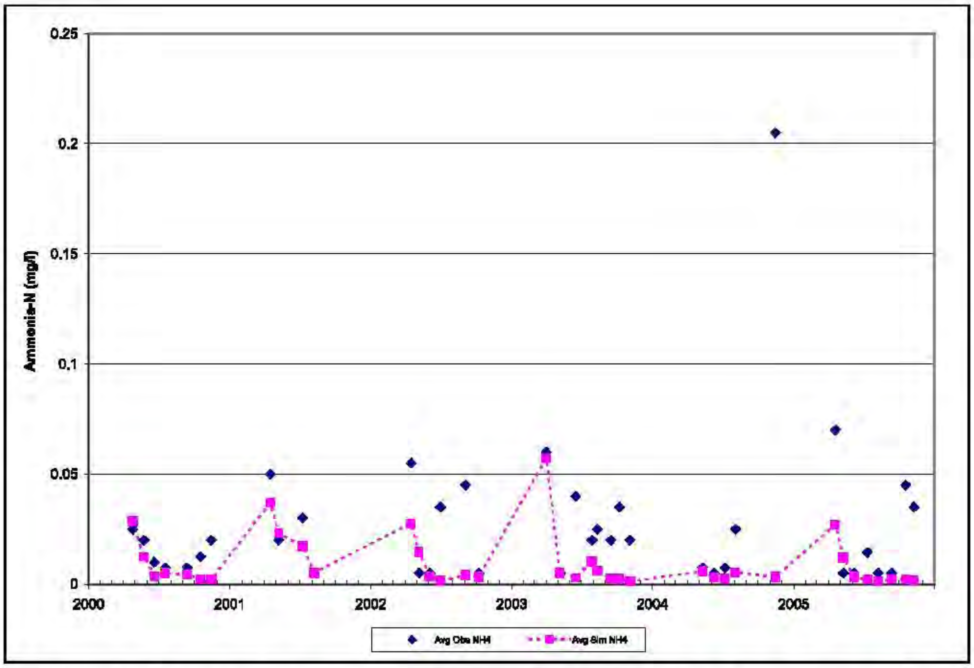

Figure C-21: Liberty Reservoir BCDPW Station NPA0059 Surface Observed and Simulated (Calibration) NH4 Concentrations on Sampling Dates

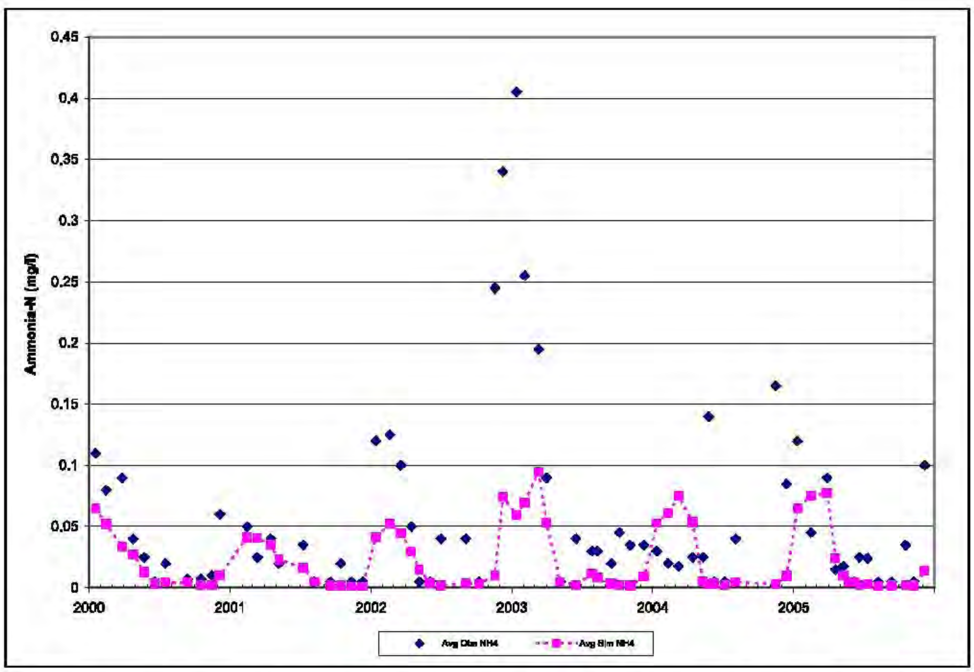

Figure C-22: Liberty Reservoir BCDPW Station NPA0042 Surface Observed and Simulated (Calibration) NH4 Concentrations on Sampling Dates

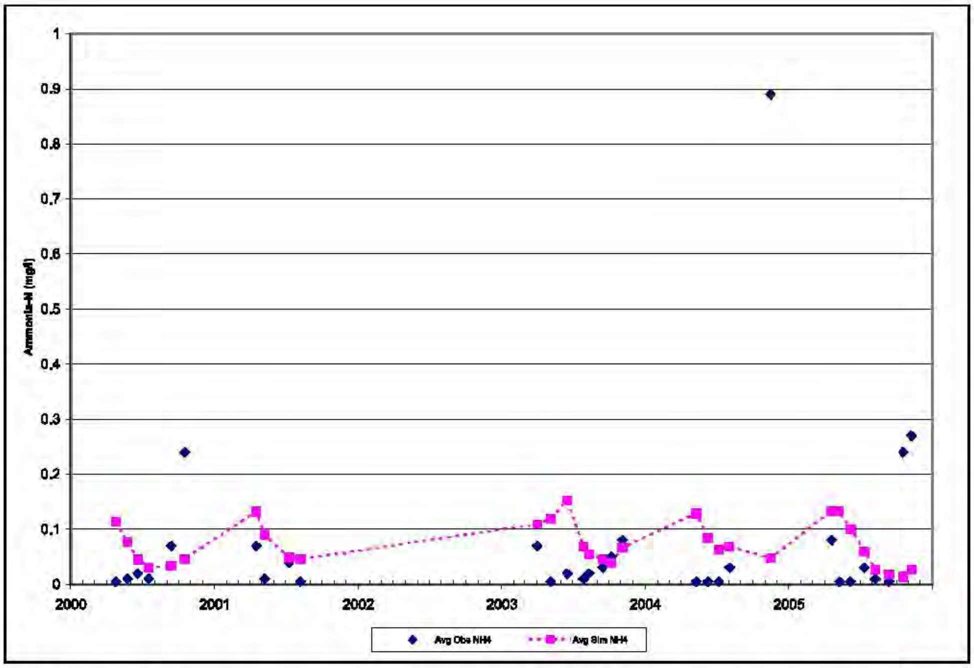

Figure C-23: Liberty Reservoir BCDPW Station NPA0067 Bottom Observed and Simulated (Calibration) NH4 Concentrations on Sampling Dates

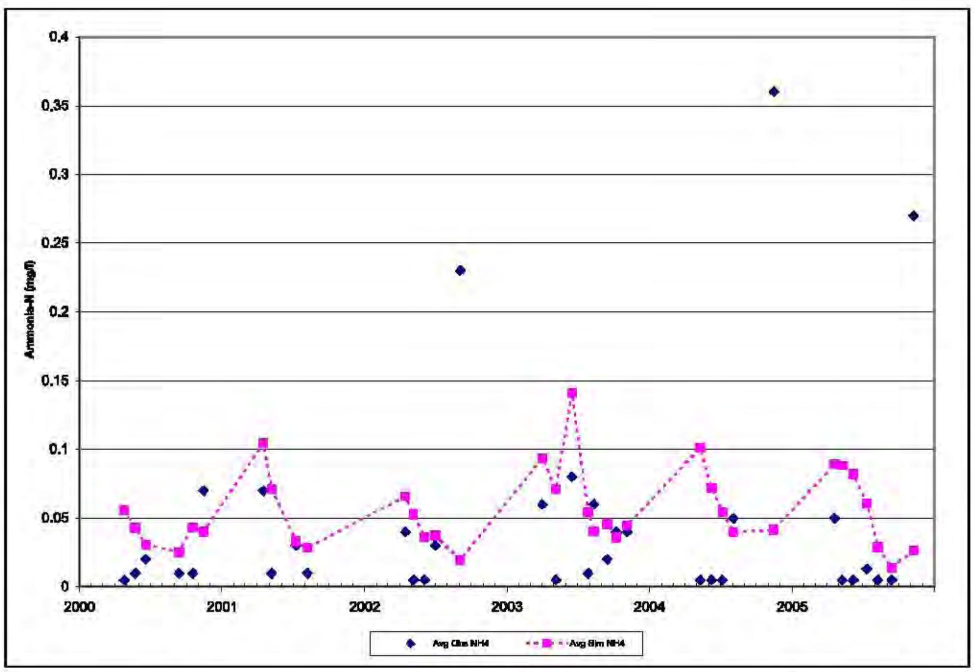

Figure C-24: Liberty Reservoir BCDPW Station NPA0059 Bottom Observed and Simulated (Calibration) NH4 Concentrations on Sampling Dates

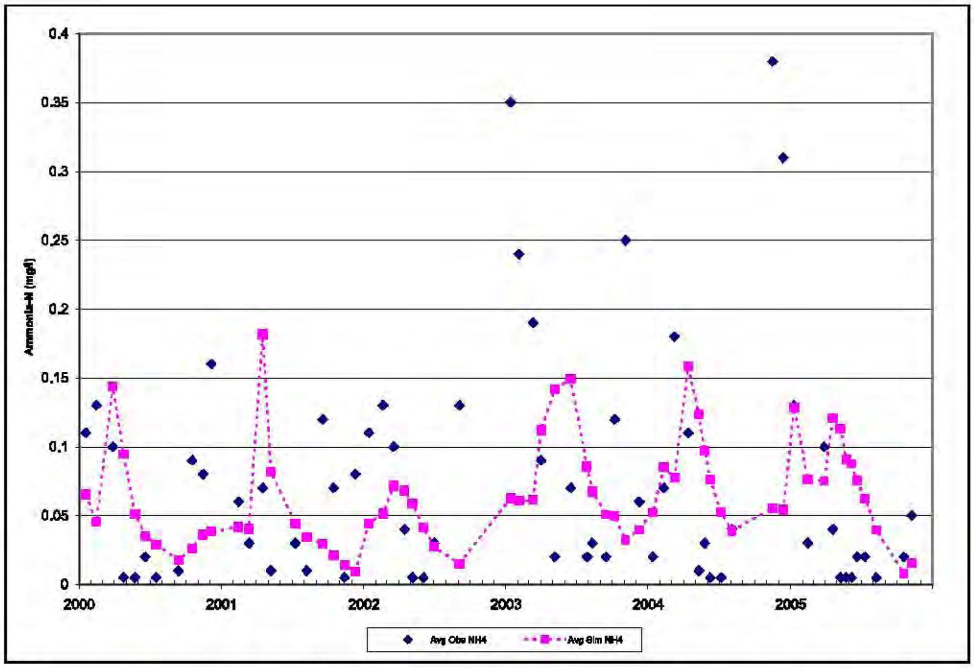

Figure C-25: Liberty Reservoir BCDPW Station NPA0042 Bottom Observed and Simulated (Calibration) NH4 Concentrations on Sampling Dates

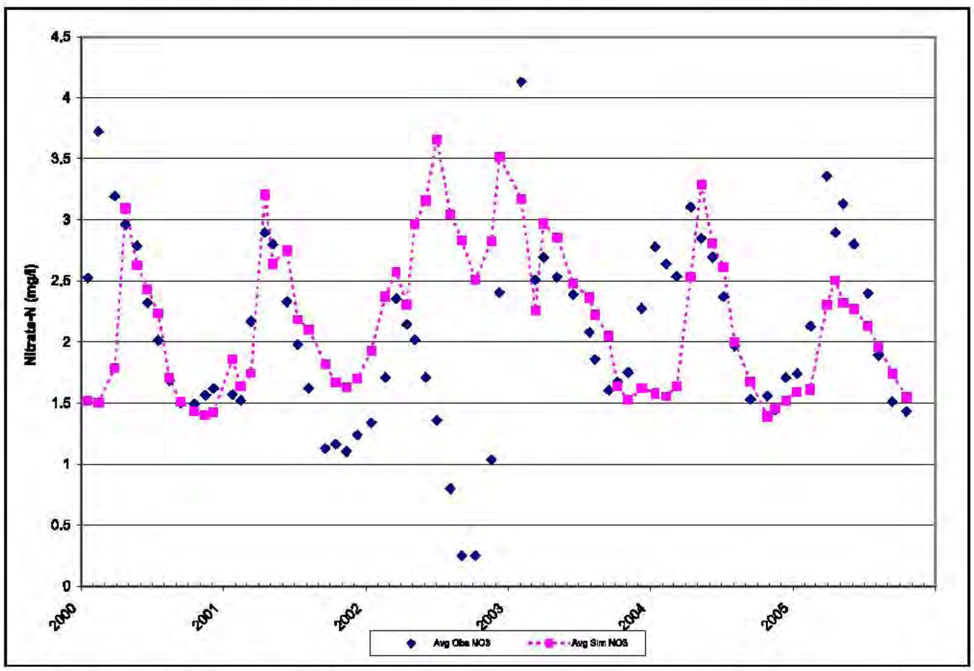

Figure C-26: Liberty Reservoir BCDPW Station NPA0105 Surface Observed and Simulated (Calibration) NO3 Concentrations on Sampling Dates

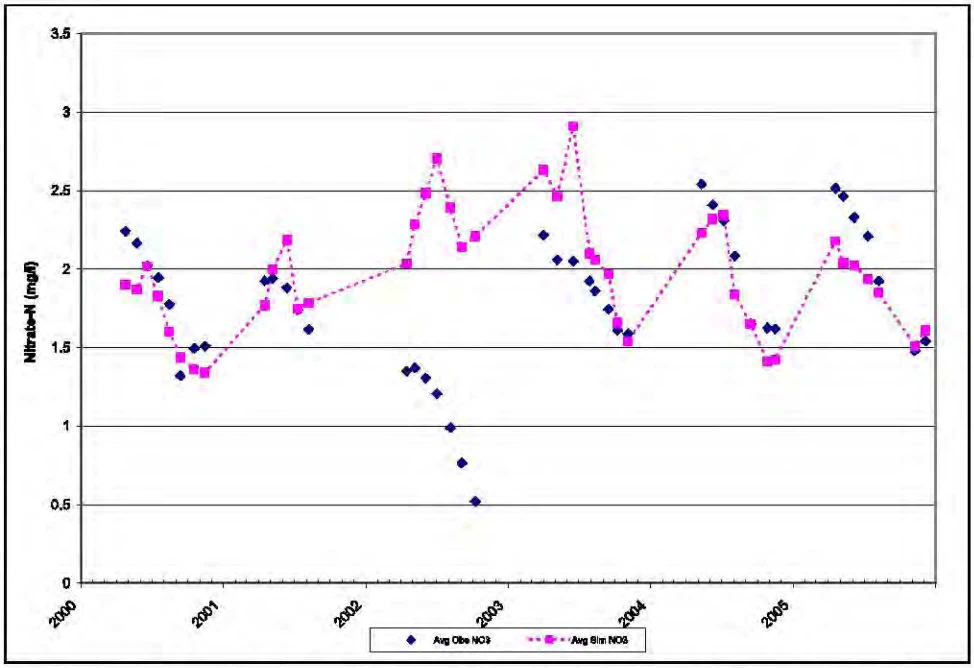

Figure C-27: Liberty Reservoir BCDPW Station NPA0067 Surface Observed and Simulated (Calibration) NO3 Concentrations on Sampling Dates

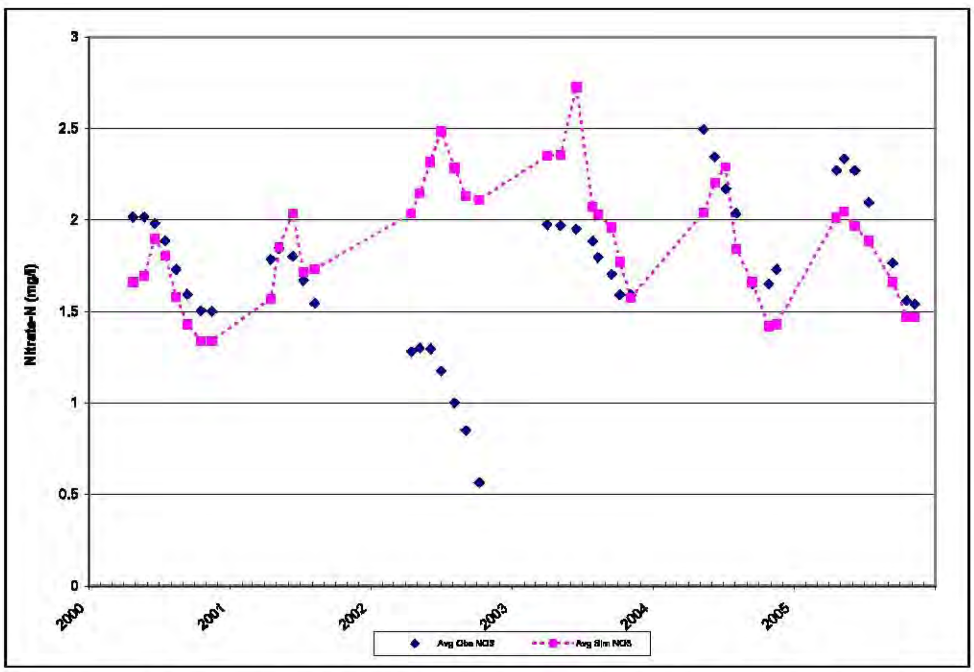

Figure C-28: Liberty Reservoir BCDPW Station NPA0059 Surface Observed and Simulated (Calibration) NO3 Concentrations on Sampling Dates

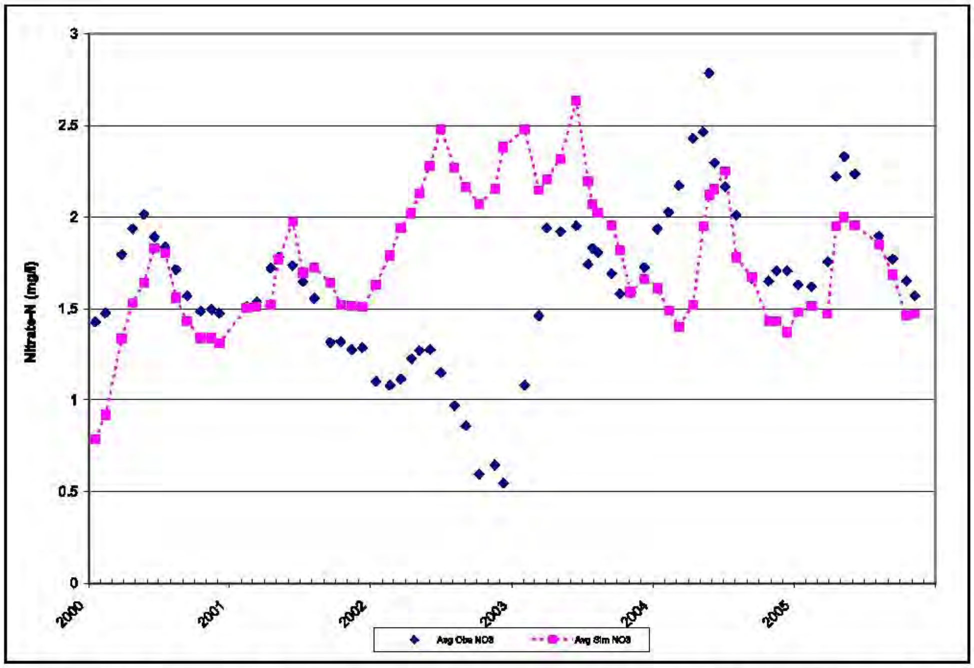

Figure C-29: Liberty Reservoir BCDPW Station NPA0042 Surface Observed and Simulated (Calibration) NO3 Concentrations on Sampling Dates

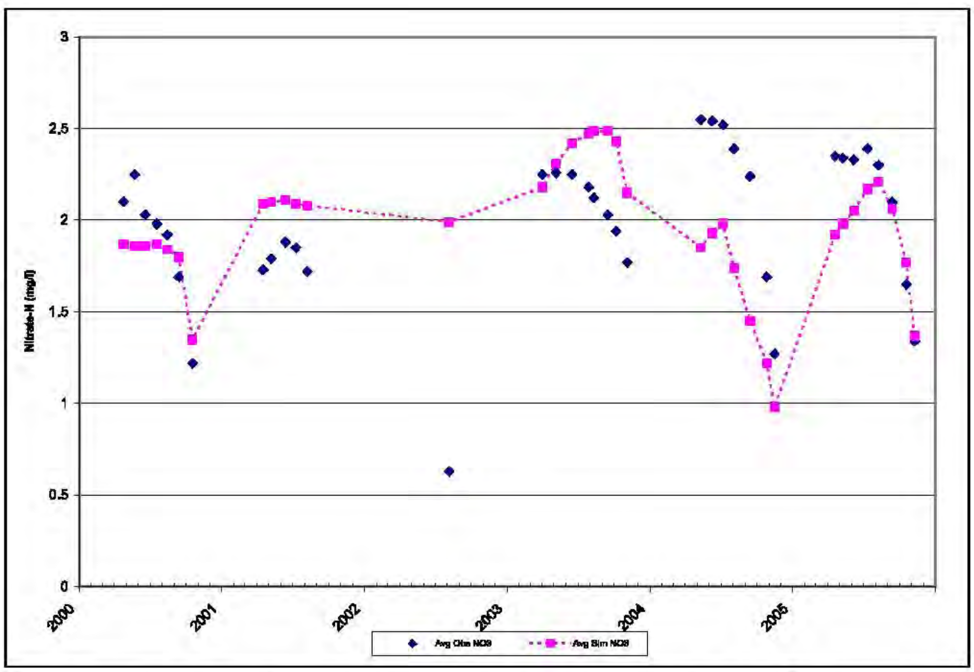

Figure C-30: Liberty Reservoir BCDPW Station NPA0067 Bottom Observed and Simulated (Calibration) NO3 Concentrations on Sampling Dates

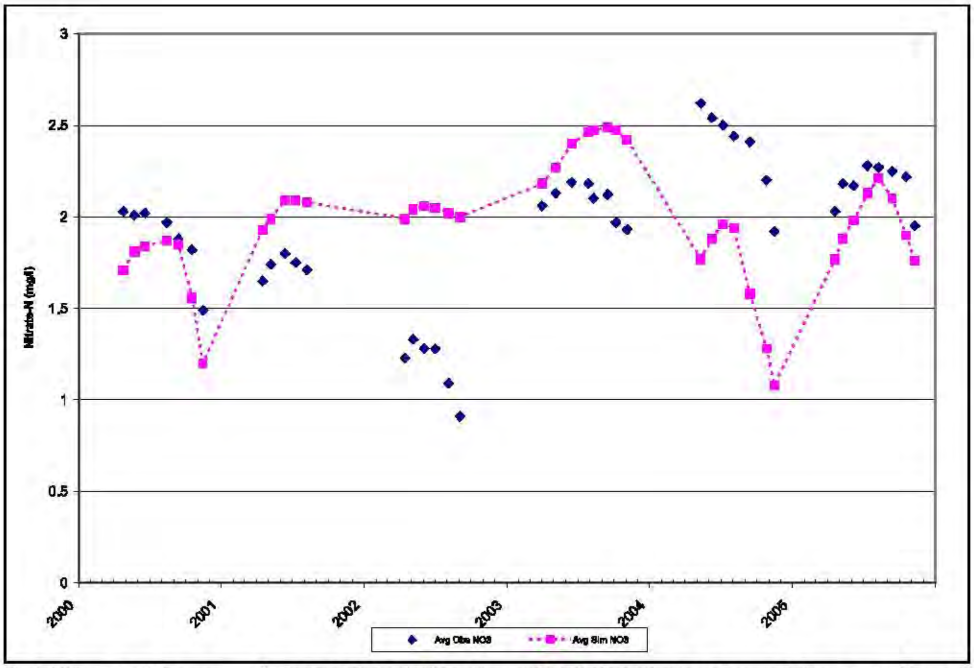

Figure C-31: Liberty Reservoir BCDPW Station NPA0059 Bottom Observed and Simulated (Calibration) NO3 Concentrations on Sampling Dates

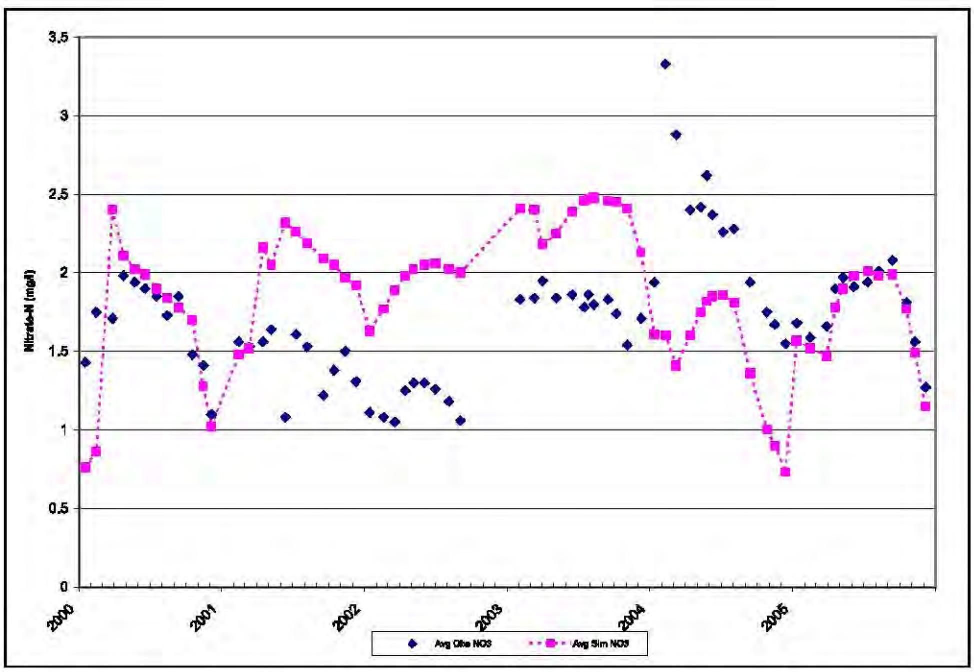

Figure C-32: Liberty Reservoir BCDPW Station NPA0042 Bottom Observed and Simulated (Calibration) NO3 Concentrations on Sampling Dates

Appendix D

Technical Approach Used to Generate Maximum Daily Loads

Summary

This appendix documents the technical approach used to define MDLs of phosphorus and sediment consistent with the average annual TMDLs, which are protective of water quality standards in Liberty Reservoir. The approach builds upon the modeling analysis that was conducted to determine the loadings of phosphorus and sediment, and can be summarized as follows.

- The approach defines MDLs for each of the source categories.
- The approach builds upon the TMDL modeling analysis that was conducted to ensure that average annual loading targets result in the achievement of water quality standards.
- The approach converts daily time-series loadings into TMDL values in a manner that is consistent with available EPA guidance on generating daily loads for TMDLs.
- The approach considers a daily load level of a resolution based on the specific data that exists for each source category.

Introduction

This appendix documents the development and application of the approach used to define total maximum daily loads on a daily basis. It is divided into sections discussing:

- Basis for approach
- Options considered
- Selected approach
- Results of approach

Basis for approach

The overall approach for the development of daily loads was based upon the following factors:

- **Average Annual TMDLs:** The basis of the average annual phosphorus TMDL is that cumulative high nutrient loading rates lead to eutrophication. Thus, the average annual phosphorus loads were calculated to be protective of the aquatic life designated use of Liberty Reservoir. Similarly, high sediment loading rates lead to a loss of reservoir storage capacity, and average annual sediment loads were calculated to protective of the public water supply designated use of the reservoir.

- **The CBP P5.3.2 Liberty Reservoir Watershed Model Phosphorus and Sediment Loads:** As described in Section 2.2.1, the phosphorus and sediment loads from the Liberty Reservoir watershed model are based on EOS loads from the CBP P5.3.2 watershed model, refined for these TMDLs via statistical analysis of monitoring data collected by BCDPW in the Liberty Reservoir watershed.
- **Draft EPA guidance document entitled "Developing Daily Loads for Load-based TMDLs"**: This guidance document provides options for defining MDLs when using TMDL approaches that generate daily output (US EPA 2007).

The rationale for developing TMDLs expressed as *daily* loads was to accept the existing average annual TMDLs, but then develop a method for converting these numbers to a MDL – in a manner consistent with EPA guidance and available information.

Options Considered

The draft EPA guidance document for developing daily loads does not specify a single approach that must be adhered to, but rather it contains a range of acceptable options for calculating MDLs. The selection of a specific method for translating a time-series of allowable loads into the expression of a TMDL requires decisions regarding both the level of resolution (e.g., single daily load for all conditions vs. loads that vary with environmental conditions) and level of probability associated with the TMDL.

This section describes the range of options that were considered when developing MDLs for the Liberty Reservoir.

<u>Level of Resolution</u>

The level of resolution pertains to the amount of detail used in specifying the MDL. The draft EPA guidance on daily loads provides three categories of options for level of resolution, all of which are potentially applicable for the Liberty Reservoir phosphorus and sediment TMDLs:

1. **Representative daily load:** In this option, a single daily load (or multiple representative daily loads) is specified that covers all time periods and environmental conditions.
2. **Flow-variable daily load:** This option allows the MDL to vary based upon the observed flow condition.
3. **Temporally-variable daily load:** This option allows the MDL to vary based upon seasons or times of varying source or water body behavior.

<u>Probability Level</u>

All TMDLs have some probability of being exceeded, with the specific probability being explicitly specified or implicitly assumed. This level of probability directly or indirectly reflects two separate phenomena:

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often

conditions can allowably surpass the combined magnitude and duration components.

2. Pollutant loads, especially from wet weather sources, typically exhibit a large degree of variability over time. It is rarely practical to specify a "never to be exceeded value" for a daily load, as essentially any loading value has some finite probability of being exceeded.

The draft daily load guidance document states that the probability component of the MDL should be "based on a representative statistical measure" that is dependent upon the specific TMDL and best professional judgment of the developers. This statistical measure represents how often the MDL is expected/allowed to be exceeded. The primary options for selecting this level of protection would be:

1. **The MDL reflects some central tendency:** In this option, the MDL is based upon the mean or median value of the range of loads expected to occur. The variability in the actual loads is not addressed.
2. **The MDL reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the MDL is based upon the allowable load that is predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence.
3. **The MDL is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the MDL based upon a characterization of the variability of daily loads. For example, selection of the 95th percentile value would result in a MDL that would be exceeded 5% of the time.

Selected Approach

The approach selected for defining MDLs for Liberty Reservoir was based upon the specific data that exists for each source category. The approach consists of unique methods for each of the following categories of sources:

- Approach for Nonpoint Sources, CAFOs, and Stormwater Point Sources
- Approach for Process Water Point Sources

<u>Approach for Nonpoint Sources, CAFOs, and Stormwater Point Sources</u>

The level of resolution selected for defining daily MDLs for Liberty Reservoir was a representative daily load, expressed as a single daily load for each loading source. This approach was chosen based upon the specific data that exists for nonpoint sources, CAFOs, and stormwater point sources.

Currently, the best available data is the Liberty Reservoir W2 model input loads, which are calculated from the refined CBP P5.3.2 Liberty Reservoir watershed model daily time series, calibrated to long-term average annual loads. It was concluded that it would not be appropriate to apply the absolute values of the Liberty Reservoir W2 model inputs to the TMDL. Rather, it was decided that best approach would be to adopt the methodology applied within Maryland's non-tidal sediment and nutrient TMDLs, which is a statistically-based estimate using the annual loads and the distribution of simulated daily loads. Since the TMDL loads and simulated daily loads are based on the same model hydrology, this approach assumes that the distribution of the daily simulated river reach loads represents the distribution of delivered EOS loads used in the TMDL, and therefore they could be used to calculate a normalized statistical parameter to estimate the MDLs.

The MDL was estimated based on three factors: a specified probability level, the average annual phosphorus or sediment TMDL, and the coefficient of variation (CV) of the total simulated daily loads entering Liberty Reservoir. The probability level (or exceedance frequency) is based upon guidance from EPA (US EPA 1991) where examples suggest that when converting from a long-term average to a daily value, the z-score corresponding to the 99th percentile of the log-normal probability distribution should be used.

CBP P5.3.2 Liberty Reservoir watershed model reach simulations consisted of a daily time series beginning in 2000 and extending to the year 2005. The CV was estimated by first converting the daily phosphorus or sediment load values to a log distribution and then verifying that the results approximated a normal distribution (see Figures D-1 and D-2 for total phosphorus and sediment, respectively). Next, the CV for this distribution was calculated using the arithmetic mean and standard deviation results from the log transformation. The log-transformed values were used to reduce the possible influence of outliers. The resulting CVs (0.490 for phosphorus and 0.069 for sediment) were calculated using the following equation:

$$CV = \frac{\beta}{\alpha} \qquad \text{(Equation D-1)}$$

Where:

CV = coefficient of variation

$\beta = \alpha\sqrt{e^{\sigma^2} - 1}$

$\alpha = e^{(\mu + 0.5*\sigma^2)}$

α = mean (arithmetic)

β = standard deviation (arithmetic)

μ= mean of logarithms

σ=standard deviation of logarithms

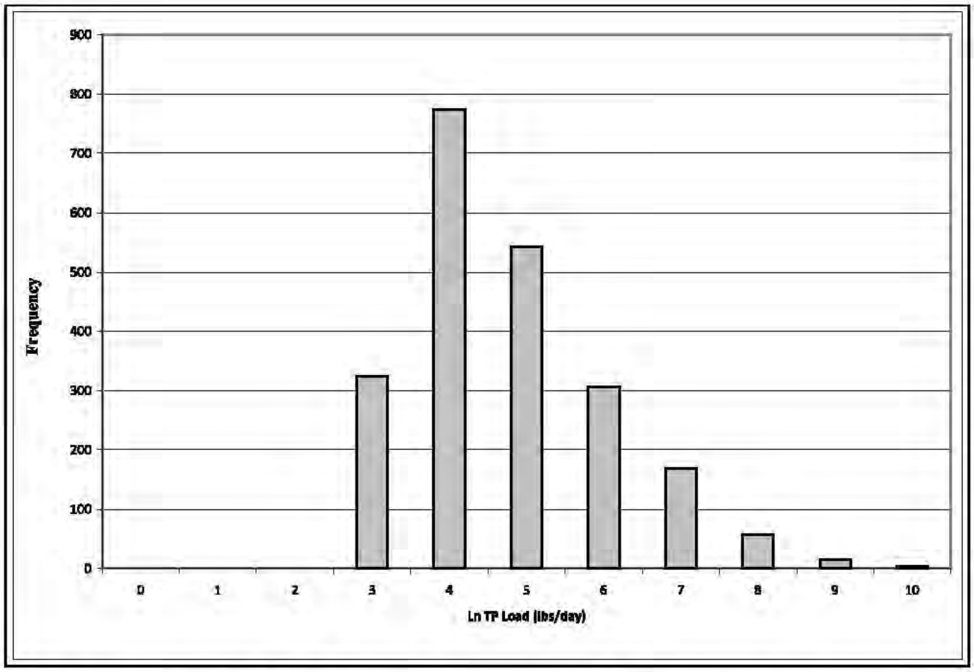

Figure D-1: Histogram of CBP River Segment Daily Phosphorus Simulation Results for Liberty Reservoir

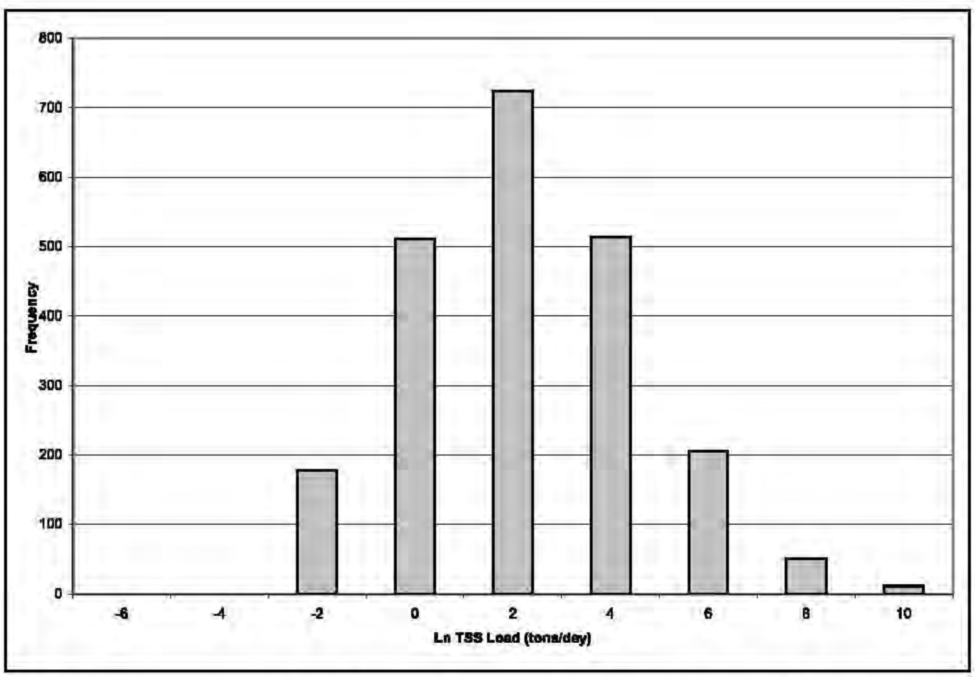

Figure D-2: Histogram of CBP River Segment Daily Sediment Simulation Results for Liberty Reservoir

The MDL for each contributing source is estimated as the long-term average annual load multiplied by a factor that accounts for expected variability of daily loading values. The equation is as follows:

$$MDL = LTA * e^{(z\sigma - 0.5\sigma^2)} \qquad \text{(Equation D-2)}$$

Where:

MDL = Maximum daily load
LTA = Long-term average (average annual load)
Z = z-score associated with target probability level
$\sigma^2 = \ln(CV^2+1)$
CV = Coefficient of variation based on arithmetic mean and standard deviation

Using a z-score associated with the 99th percent probability, the CVs of 0.490 and 0.069 for phosphorus and sediment, respectively, and consistent units, the resulting dimensionless conversion factor from long-term average loads to a maximum daily value is 2.64 and 1.17 for phosphorus and sediment, respectively. The average annual Liberty Reservoir phosphorus TMDL is reported in lbs/yr, and the conversion from lbs/yr to a MDL in lbs/day is 0.0072 (e.g. 2.64/365). The average annual Liberty Reservoir sediment TMDL is reported in tons/yr, and the conversion from tons/yr to a MDL in tons/day is 0.0032 (e.g. 1.17/365).

Approach for Process Water Point Sources

The TMDL also considers contributions from other point sources (*i.e.*, sources other than stormwater point sources) in the watershed that have NPDES permits with phosphorus or sediment limits. As these sources are generally minor contributors to overall nutrient or sediment loads, the TMDL analysis that defined the average annual TMDL did not propose any reductions for these sources and held each of them constant at their existing technology-based NPDES permit monthly (or daily if monthly was not specified) limit for the entire year.

The approach used to determine MDLs for these sources was dependent upon whether a MDL was specified within the permit. If a maximum daily limit was specified, then the reported average flow was multiplied by the daily maximum limit to obtain a MDL. If a maximum daily limit was not specified, the MDLs were calculated based on the guidance provided in the Technical Support Document (TSD) for Water Quality-based Toxics Control (US EPA 1991). The long-term average annual TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99th percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual Liberty Reservoir phosphorus TMDL is reported in lbs/yr, and the conversion from lbs/yr to a MDL in lbs/day is 0.0072 (e.g. 2.64/365). The average annual Liberty Reservoir sediment TMDL is reported in tons/yr, and the conversion from tons/yr to a MDL in tons/day is 0.0032 (e.g. 1.17/365).

None of the permitted process water point sources in the Liberty Reservoir watershed have daily maximum phosphorus or sediment concentrations, so the MDL was calculated based on the TSD guidance.

Margin of Safety
The MOS for the Liberty Reservoir phosphorus TMDL was set equal to 5% of the total TMDL (including the MOS), or 5.26% of the total WLAs and LAs. The MOS for the Liberty Reservoir sediment TMDL is implicit.

Results of Approach

This section lists the results of the selected approach to define MDLs for the Liberty Reservoir.

- Calculation Approach for Nonpoint Sources, CAFOs, and Stormwater Point Sources

For Phosphorus:

LA_{LR} (lbs/day) = Average Annual TMDL LA_{LR} (lbs/yr) * 0.0072

NPDES Stormwater WLA_{LR} (lbs/day) = Average Annual TMDL NPDES Stormwater WLA_{LR} (lbs/yr) * 0.0072

CAFO WLA_{LR} (lbs/day) = Average Annual TMDL NPDES Stormwater WLA_{LR} (lbs/yr) * 0.0072

For Sediment:

LA_{LR} (tons/day) = Average Annual TMDL LALR (tons/yr) * 0.0032

Stormwater WLALR (tons/day) = Average Annual TMDL Stormwater WLA_{LR} (tons/yr) * 0.0032

CAFO WLA_{LR} (tons/day) = Average Annual TMDL Stormwater WLA_{LR} (tons/yr) * 0.0032

- Calculation Approach for Process Water Point Sources
    - For permits with a daily maximum limit:

Process Water WLA_{LR} (lbs/day; tons/day) = Permit flow (millions of gallons per day (mgd)) * Daily maximum permit limit (mg/l) * 0.0042

- For permits without a daily maximum limit:

Process Water WLA_{LR} (lbs/day; tons/day) = Process Water WLA (lbs/yr)* 0.0072 (phosphorus)/0.0032 (sediments)

Table D-1: Summary of Liberty Reservoir Total Phosphorus MDLs (lbs/day)

MDL (lbs/day)	=	LA_{LR}	+	CAFO WLA_{LR}	+	NPDES Stormwater WLA_{LR}	+	Process Water WLA_{LR}	+	MOS
300.3	=	180.0	+	3.1	+	80.9	+	21.2	+	15.0

Table D-2: Summary of Liberty Reservoir Sediment MDLs (tons/day)

MDL (tons/day)	=	LA_{LR}	+	CAFO WLA_{LR}	+	NPDES Stormwater WLA_{LR}	+	Process Water WLA_{LR}		MOS
51.6	=	33.5	+	0.02	+	17.6	+	0.5	+	Implicit

Technical Memorandum

Significant Phosphorus and Sediment Point Sources in the Liberty Reservoir Watershed

The U.S. Environmental Protection Agency (EPA) requires that Total Maximum Daily Load (TMDL) allocations account for all significant sources of each impairing pollutant (CFR 2012a). This technical memorandum identifies the significant point sources of phosphorus and sediment in the Liberty Reservoir watershed. Detailed allocations are provided for those point sources included within the Liberty Reservoir Process Water Waste Load Allocations (WLAs) and National Pollutant Discharge Elimination System (NPDES) Regulated Stormwater WLAs. These are conceptual values that are designed to meet the TMDL thresholds. Phosphorus and sediment loads from concentrated animal feeding operations (CAFOs) are also assigned a WLA within the TMDL, but the WLA for CAFOs is not presented here in any more specific detail than it is in the main report. The State reserves the right to allocate the TMDLs among different sources in any manner that is reasonably calculated to protect designated uses from nutrient or sediment related impacts.

The Liberty Reservoir Phosphorus and Sediment TMDLs are presented in terms of an average annual load established to be protective of the recreational, aquatic life, and public water supply designated uses of the reservoir. WLAs have been calculated for NPDES regulated individual industrial, individual municipal separate storm sewer systems (MS4s), general industrial stormwater, and general MS4 permits in the Liberty Reservoir watershed. The permits can be grouped into two categories, process water and stormwater.

The process water category includes those non-rainfall driven loads from facilities capable of discharging phosphorus and sediments. It specifically includes the following sources: (1) municipal waste water treatment plants (WWTPs); (2) industrial process water permits; and (3) mineral mines. There are no municipal WWTPs or mineral mines located in the watershed. There are eleven industrial process water permits in the Liberty Reservoir watershed that are capable of discharging phosphorus and/or sediments.

The Liberty Reservoir phosphorus and sediment WLAs for the process water point sources are based on the WLAs assigned to the same facilities within the Chesapeake Bay TMDL (US EPA 2010) and Maryland’s Phase I and Phase II Watershed Implementation Plans (WIPs) (MDE 2010, 2012). These WLAs are loading caps that are designed to meet the Phase II 2025 final implementation goals for the Chesapeake Bay TMDL and accommodate future growth after full implementation of the TMDL in 2025. MDE has identified eleven industrial process water facilities that discharge phosphorus and sediments in the Liberty Reservoir watershed. Within the Chesapeake Bay TMDL, industrial facilities capable of discharging phosphorus and sediments in their process water were assigned a WLA based on the results of monitoring data collected as part of their permit requirements or best professional judgment. These WLAs were adopted for the Liberty Reservoir Phosphorus and Sediment TMDLs. See Sections 2.2.2 and 4.6 of the main report for further details. Tables 1 and 2 provide one possible scenario for the distribution of the average annual phosphorus and sediment point source WLAs, respectively, within the Liberty Reservoir watershed.

The stormwater category includes all NPDES regulated stormwater discharges. There are 25 NPDES Phase I and Phase II stormwater permits identified within the Liberty Reservoir watershed. These include both individual and general NPDES Phase I and II stormwater permits. The permits are regulated based on Best Management Practices (BMPs) and do not include TP or TSS limits. In the absence of TP and TSS limits, the baseline loads for these NPDES regulated stormwater discharges are calculated using the CBP P.3.2 2009 Progress Scenario nonpoint source loads from the urban land use within the watershed. These calculations are described in more detail below.

Individual WLAs have been calculated for each of the Phase I county MS4 permits in the watershed and the SHA Phase I MS4 permit. An aggregate WLA has been calculated for the general municipal Phase II MS4 permits for the towns of Hampstead, Manchester, and Westminster. Finally, an aggregate WLA was also calculated for all other NPDES regulated stormwater permits, collectively termed “Other NPDES Regulated Stormwater”, which include general state and federal Phase II MS4 permits, all industrial facilities permitted for stormwater discharges, and general construction permits.

The computational framework chosen for the Liberty Reservoir Phosphorus and Sediment TMDLs was 1) a refined version of the Chesapeake Bay Program Phase 5.3.2 (CBP P5.3.2) watershed model, which was used to estimate the phosphorus and sediment loads entering the reservoir during the 2001-2005 simulation period; 2) a CE-QUAL-W2 (W2) model of the Liberty Reservoir itself, which was used to simulate the impact that the phosphorus and sediment loads from the watershed model have on water quality in the reservoir; and 3) the CBP P5.3.2 watershed model 2009 Progress Scenario, which was used to estimate the current, or baseline, loads to the reservoir. The nonpoint source phosphorus and sediment loads generated within the Liberty Reservoir watershed are calculated as edge-of-stream (EOS) loads and represent a long-term average loading rate. Further details of the nonpoint source phosphorus and sediment load calculations can be found in Sections 2.2, 4.2, and 4.3 of the main TMDL report and the modeling report for this TMDL, *Modeling Framework for Simulating Hydrodynamics and Water Quality in Liberty Reservoir* (ICPRB 2012).

In order to calculate the individual and aggregate NPDES stormwater WLAs, MDE further refined the CBP P5.3.2 urban land-use. The refined CBP P5.3.2 land-use contains the specific level of detail needed to determine individual and aggregate WLAs for the Baltimore and Carroll counties Phase I jurisdictional MS4s, the SHA Phase I MS4, the Phase II jurisdictional MS4s, and “Other NPDES regulated stormwater,”. The methods used by MDE to refine the CBP P5.3.2 urban land-use are described within MDE’s documentation, *CBP P5.3.2 Land-Use and MDE Urban Source Sector Delineation - Development Methodology* (MDE 2011).

The baseline phosphorus and sediment loads were estimated for the NPDES regulated stormwater source sectors using MDE’s refinement of CBP P5.3.2 watershed model 2009 Progress Scenario land-use. The controllable loads (CBP P5.3.2 “E3” Scenario Load – CBP P5.3.2 2009 Progress Scenario Load) for each NPDES regulated stormwater source sector were calculated based on MDE's refinement of both the "E3" and 2009 Progress CBP P5.3.2 watershed model scenarios. The WLAs for each regulated stormwater source sector were then calculated based on applying an equal percent reduction to the controllable loads for each regulated stormwater source sector, along with other land-uses, as described in Section 4.6 of the main TMDL report. Reductions for all NPDES regulated stormwater source sectors were not allowed to exceed 75% of the controllable load, which MDE has defined as the maximum feasible reduction.

Table 3 identifies all of the applicable NPDES stormwater permits in the Liberty Reservoir watershed. Tables 4 and 5 provide one possible scenario for the distribution of the average annual phosphorus and sediment WLAs to the NPDES regulated stormwater source sectors in the Liberty Reservoir watershed, respectively (See Sections 4.2 - 4.6 of the main report for further details).

As per the Clean Water Act (CWA) all CAFOs are required to obtain NPDES permits for their discharges or potential discharges (CFR 2012b). In January, 2009, Maryland implemented new regulations governing CAFOs (COMAR 2012a,b), which were approved by the EPA in January, 2010. Under these regulations, CAFOs are required to fulfill the conditions of a general permit. These conditions include instituting a Comprehensive Nutrient Management Plan (CNMP) that meets the Nine Minimum Standards to Protect Water Quality. The general permit also prohibits the discharge of pollutants, including nutrients, from CAFO production areas except as the result of an event greater than the 25-year, 24-hour storm. Based on the TMDL methodology approach of applying an equal percent reduction to all controllable loads, subject to a maximum reduction for permitted sources of 75%, a 59% reduction in phosphorus loads and 50% reduction on sediment loads is required from CAFOs in the Liberty Reservoir TMDLs. Table 6 provides the baseline phosphorus load and WLA for CAFOs. Table 7 provides the baseline sediment load and WLA for CAFOs.

Table 1: Liberty Reservoir Phosphorus TMDL Process Water Point Source WLAs

Facility Name[1,2]	NPDES #	Permit Type		WLA Type	Flow (MGD)[3]	Baseline Load (lbs/yr)	WLA (tons/yr)
CONGOLEUM CORPORATION	MD0001384	Industrial	Individual	Individual	0.12	88	160
BTR HAMPSTEAD, LLC	MD0001881	Industrial	Individual	Aggregate	N/A[4]	3,321	2,338
CITY OF WESTMINSTER KOONTZ WELL	MD0058556	Industrial	Individual	Aggregate			
S & G CONCRETE - FINKSBURG PLANT	MDG492472	Industrial	Individual	Aggregate			
CARROLL COUNTY FAMILY YMCA	MDG766057	Industrial	General	Aggregate			
THE BOSTON INN, INC.	MDG766199	Industrial	General	Aggregate			
FOUR SEASONS SPORTS COMPLEX	MDG766210	Industrial	General	Aggregate			
FREEDOM SWIM CLUB	MDG766371	Industrial	General	Aggregate			
GREEN VALLEY SWIM CLUB	MDG766379	Industrial	General	Aggregate			
MCDANIEL COLLEGE	MDG766048	Industrial	General	Aggregate			
GLYNDON TRACE CONDOMINIUMS	MDG766199	Industrial	General	Aggregate			
Total						**3,409**	**2,498**

Notes:[1] Two municipal Water Treatment Plants (WTPs) (Cranberry WTP, NPDES # MD0067644; and Freedom District WTP, NPDES# MD0067652) have been identified within the watershed, but are not included within the analysis, since they withdraw water from the watershed stream system. Therefore, any TP and TSS loads discharged from the plants are representative of a pass through condition.

[2] Two hydrostatic testing permits (Maryland Military Facility – Camp Fretterd, NPDES# MDG675043; and Pearlstone Family Camp, NPDES# MDG675029) have also been identified within the watershed but are not included within the analysis, since they both discharge to groundwater rather than surface water, and therefore there are no potential TP or TSS loadings from the permits.

[3] MGD: Millions of Gallons per Day.

[4] N/A: Not Applicable.

Table 2: Liberty Reservoir Sediment TMDL Process Water Point Source WLAs

Facility Name[1,2]	NPDES #	Permit Type		WLA Type	Flow (MGD)	Baseline Load (tons/yr)	WLA (tons/yr)
CONGOLEUM CORPORATION	MD0001384	Industrial	Individual	Individual	0.12	1	4
BTR HAMPSTEAD, LLC	MD0001881	Industrial	Individual	Aggregate	N/A	14	57
CITY OF WESTMINSTER KOONTZ WELL	MD0058556	Industrial	Individual	Aggregate			
S & G CONCRETE - FINKSBURG PLANT	MDG492472	Industrial	Individual	Aggregate			
CARROLL COUNTY FAMILY YMCA	MDG766057	Industrial	General	Aggregate			
THE BOSTON INN, INC.	MDG766199	Industrial	General	Aggregate			
FOUR SEASONS SPORTS COMPLEX	MDG766210	Industrial	General	Aggregate			
FREEDOM SWIM CLUB	MDG766371	Industrial	General	Aggregate			
GREEN VALLEY SWIM CLUB	MDG766379	Industrial	General	Aggregate			
MCDANIEL COLLEGE	MDG766048	Industrial	General	Aggregate			
GLYNDON TRACE CONDOMINIUMS	MDG766199	Industrial	General	Aggregate			
Total						**15**	**61**

Notes:[1] Two municipal WTPs (Cranberry WTP, NPDES # MD0067644; and Freedom District WTP, NPDES# MD0067652) have been identified within the watershed, but are not included within the analysis, since they withdraw water from the watershed stream system. Therefore, any TP and TSS loads discharged from the plants are representative of a pass through condition.

[2] Two hydrostatic testing permits (Maryland Military Facility – Camp Fretterd, NPDES# MDG675043; and Pearlstone Family Camp, NPDES# MDG675029) have also been identified within the watershed but are not included within the analysis, since their loadings are considered to be *de minimis* in terms of the overall watershed TP and TSS loadings.

Table 3: Liberty Reservoir NPDES Stormwater Permits

NPDES Permit #[1]	Facility Name	NPDES Regulated Stormwater WLA Sector[2]
N/A - 02SW1965	BALTIMORE COUNTY BUREAU OF HIGHWAYS - SHOP 3	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1219	BFI WASTE SERVICES, LLC - FINKSBURG	OTHER NPDES REGULATED STORMWATER
N/A - 02SW3001	BULLOCK'S MEATS, INC.	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1824	C AND C MULCH PROCESSING, LLC	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1755	CARROLL COUNTY REGIONAL AIRPORT	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1452	CONDON'S AUTO PARTS, INC.	OTHER NPDES REGULATED STORMWATER
N/A - 02SW2006	GENERAL DYNAMICS ROBOTIC SYSTEMS	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0664	HODGES LANDFILL	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0954	JONES AUTO & SALVAGE	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1144	M & M TRUCK & EQUIPMENT CO., INC.	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0660	NORTHERN MUNICIPAL LANDFILL	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1345	SHA - WESTMINSTER SHOP	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1908	SMITH BROTHERS AUTO PARTS	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0078	THOMAS, BENNETT & HUNTER, INC. - SHOP FACILITY	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0794	TOBACCO TECHNOLOGY, INC.	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0115	CJ MILLER. LLC	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0719	MARYLAND PAVING - FINKSBURG	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0029	MARANDA INDUSTRIES	OTHER NPDES REGULATED STORMWATER
MDR05550	CITY OF HAMPSTEAD MS4	MUNICIPAL PHASE II MS4
MDR05550	CITY OF MANCHESTER MS4	MUNICIPAL PHASE II MS4
MDR05550	CITY OF WESTMINSTER MS4	MUNICIPAL PHASE II MS4
MD0068314	BALTIMORE COUNTY MS4	BALTIMORE COUNTY PHASE I MS4
MD0068331	CARROLL COUNTY MS4	CARROLL COUNTY PHASE I MS4
MD0055501	STATE HIGHWAY ADMINISTRATION MS4 (PHASE I)	SHA PHASE I MS4
N/A	MDE GENERAL PERMIT TO CONSTRUCT	OTHER NPDES REGULATED STORMWATER

Notes:[1] N/A: Permit does not have an NPDES number. For the industrial stormwater permits, the permit number listed is the MDE permit application number.
[2] Although not listed in this table, some individual permits from Table 2 and 3 incorporate stormwater requirements and are accounted for within the “Other NPDES Regulated Stormwater WLA”, as well additional Phase II permitted MS4s, such as military bases, hospitals, etc.

Table 4: Liberty Reservoir Phosphorus TMDL NPDES Regulated Stormwater WLAs

NPDES Regulated Stormwater Sector	**NPDES #**	**Baseline Load** (lbs/yr)	**WLA** (lbs/year)	**Reduction** (%)
Baltimore County Phase I MS4	MD0068314	1,037	524	49
Carroll County Phase I MS4	MD0068331	12,300	6,102	50
SHA Phase I MS4	MD0055501	1,231	677	45
Municipal Phase II MS4s	MDR05550	1,672	893	47
"Other NPDES Regulated Stormwater"	N/A	3,848	2,981	23
Total		**20,088**	**11,177**	**44**

Table 5: Liberty Reservoir Sediment TMDL NPDES Regulated Stormwater WLAs

NPDES Regulated Stormwater Sector	**NPDES #**	**Baseline Load** (tons/yr)	**WLA** (tons/yr)	**Reduction** (%)
Baltimore County Phase I MS4	MD0068314	475	294	38
Carroll County Phase I MS4	MD0068331	4,033	2,530	37
SHA Phase I MS4	MD0055501	500	275	45
Municipal Phase II MS4s	MDR05550	611	350	43
"Other NPDES Regulated Stormwater"	N/A	2,402	2,035	15
Total		**8,021**	**5,484**	**32**

Table 6: Liberty Reservoir Phosphorus TMDL NPDES Regulated CAFO WLA

Baseline Load (lbs/yr)	**WLA** (lbs/year)	**Reduction** (%)
1,060	430	59

Table 7: Liberty Reservoir Sediment TMDL NPDES Regulated CAFO WLA

Baseline Load (tons/yr)	**WLA** (tons/year)	**Reduction** (%)
11	5	50

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APPENDIX G:

Total Maximum Daily Loads of Fecal Bacteria for the Liberty Reservoir Basin in Carroll and Baltimore Counties, Maryland

Total Maximum Daily Loads of Fecal Bacteria for the Liberty Reservoir Basin in Carroll and Baltimore Counties, Maryland

FINAL

MARYLAND
DEPARTMENT OF THE ENVIRONMENT
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Baltimore MD 21230-1718

Submitted to:

Water Protection Division
U.S. Environmental Protection Agency, Region III
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List of Abbreviations

ARCC	Average rates of correct classification
ARA	Antibiotic Resistance Analysis
BMP	Best Management Practice
BST	Bacteria Source Tracking
cfs	Cubic Feet per Second
CFR	Code of Federal Regulations
CFU	Colony Forming Units
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DNR	Maryland Department of Natural Resources
EPA	United States Environmental Protection Agency
GIS	Geographic Information System
LA	Load Allocation
MACS	Maryland Agricultural Cost Share Program
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MGD	Millions of Gallons per Day
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
MPR	Maximum Practicable Reduction
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NPDES	National Pollutant Discharge Elimination System
RCC	Rates of Correct Classification
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WQIA	Water Quality Improvement Act
WLA	Wasteload Allocation
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for fecal bacteria in the Liberty Reservoir watershed (MD basin number 02-13-09-07). Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, states are required to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards or demonstrate that water quality standards are being met.

The Maryland Department of the Environment (MDE) has identified the tributaries of Liberty Reservoir in the State of Maryland's 303(d) List as impaired by fecal bacteria and impacts to biological communities (listed in 2002). The reservoir itself is not listed as impaired by fecal bacteria, but is listed as impaired by nutrients and sediments (listed in 1996) and by methylmercury (listed in 2002). The mainstem North Branch Patapsco River, mainstem West Branch Patapsco River and Cranberry Branch and its tributaries have been designated as Use IV-P (Recreational Trout Waters and Public Water Supply) waters. Roaring Run has been designated as Use III (Nontidal Cold Water). Beaver Run, Cooks Branch, East Branch Patapsco River, Keysers Run, Locust Run, Morgan Run, Norris Run and all their tributaries have been designated as Use III-P (Nontidal Cold Water and Public Water Supply). Liberty Reservoir and all remaining tributaries have been designated as Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply). See Code of Maryland Regulations (COMAR) 26.08.02.08K. Chromium and lead impairments (listed in 1996) have been removed from the 303(d) List through a water quality analysis (WQA) submitted to EPA in September 24, 2003. This document proposes to establish a TMDL for fecal bacteria in the Liberty Reservoir watershed that will allow for attainment of the beneficial use designation of primary water contact recreation. The listing for sediments, nutrients, methylmercury in fish tissue, and impacts to biological communities will be addressed separately at a future date. MDE monitored the Liberty Reservoir watershed from 2003 to 2004 for fecal bacteria. A data solicitation for fecal bacteria was conducted by MDE in 2003, and all readily available data from the past five years were considered.

For this TMDL analysis, the Liberty Reservoir basin has been divided into six subwatersheds, which include Beaver Run (BEA0016), Middle Run (MDE0026), Morgan Run (MOR0040), Little Morgan Run (LMR0015), and North Branch Patapsco River (NPA0165). The sixth subwatershed encompasses all unmonitored areas downstream of the five stations, except the impoundment, and will be referred to as the Downstream Subwatershed. The pollutant loads set forth in this document are for these six subwatersheds. The North Branch Patapsco River subwatershed (NPA0165) was delisted in 2004 from the State of Maryland's 303(d) List, based on the long-term geometric mean analysis of fecal coliform; however, additional analysis has been conducted and the results indicate that the subwatershed is impaired; therefore, it is included in this TMDL. To establish baseline and allowable pollutant loads for this TMDL, a flow duration curve approach was employed, using bacteria data from MDE and flow strata estimated from United States Geological Survey (USGS) daily flow monitoring. The sources of fecal bacteria are estimated at five representative stations in the Liberty Reservoir watershed where samples were collected for one year. Multiple antibiotic resistance analysis (ARA) source tracking was used to determine the relative proportion of domestic (pets and human associated animals), human (human waste), livestock (agriculture-related animals), and wildlife (mammals and waterfowl) source categories.

The baseline load is estimated based on current monitoring data, using a long-term geometric mean and weighting factors from the flow duration curve. The TMDL for fecal bacteria is established after considering three different hydrological conditions: high flow and low flow annual conditions, and an average seasonal condition (the period between May 1st and September 30th, when water contact recreation is more prevalent). This allowable load is reported in units of Most Probable Number (MPN)/year and represents a long-term load estimated over a variety of hydrological conditions.

Two scenarios were developed, with the first assessing if attainment of current water quality standards could be achieved by applying maximum practicable reductions (MPRs), and the second applying higher reductions than MPRs. Scenario solutions were based on an optimization method where the objective was to minimize the overall risk to human health, assuming that the risk varies over the four bacteria source categories. In three of the subwatersheds, it was estimated that water quality standards could be attained with MPRs; however, in three subwatersheds (NPA0165, MDE0026, and the downstream subwatershed) where it was estimated that water quality standards could not be attained, higher maximum reductions were applied.

The baseline loads are summarized in the following table:

MD 8-Digit Liberty Reservoir Fecal Bacteria Baseline Loads (Billion MPN *E. coli*/year)						
Total Baseline Load	=	**Nonpoint Source BL**	+	**Stormwater BL**	+	**WWTP BL**
1,083,248	=	979,511	+	102,692	+	1,045

The MD 8-digit Liberty Reservoir TMDL, representing the sum of individual TMDLs for the six subwatersheds, is distributed between a load allocation (LA) for nonpoint sources and waste load allocations (WLA) for point sources. Point sources include any National Pollutant Discharge Elimination System (NPDES) wastewater treatment plants (WWTPs) and NPDES regulated stormwater (SW) discharges, including county and municipal separate storm sewer systems (MS4s). The margin of safety (MOS) has been incorporated using a conservative assumption by estimating the loading capacity of the stream based on a water quality endpoint concentration more stringent than the applicable MD water quality standard criterion. The *E. coli* water quality criterion concentration was reduced by 5%, from 126 MPN/100ml to 119.7 MPN/100ml.

The MD 8-digit Liberty Reservoir TMDL of fecal bacteria is presented in the following table:

MD 8-Digit Liberty Reservoir Fecal Bacteria TMDL (Billion MPN *E. coli*/year)									
TMDL	=	LA	+	WLA			+	MOS
				SW WLA	+	WWTP WLA		
361,008	=	350,638	+	9,325	+	1,045	+	Incorporated

The long-term annual average TMDL represents a reduction of approximately 67 % from the baseline load of 1,083,248 billion MPN *E. coli*/year.

Pursuant to recent EPA guidance (US EPA 2006a), maximum daily load (MDL) expressions of the long-term annual average TMDLs are also provided, as shown in the following table:

MD 8-Digit Liberty Reservoir Fecal Bacteria MDL Summary (Billion MPN *E. coli*/day)								
MDL	=	LA	+	WLA			+	MOS
				SW WLA	+	WWTP WLA		
11,580	=	11,295	+	276	+	9	+	Incorporated

Once EPA has approved a TMDL, and it is known what measures must be taken to reduce pollution levels, implementation of best management practices (BMPs) is expected to take place. MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impacts to water quality and creating the greatest risks to human health, with consideration given to ease and cost of implementation. In addition, follow-up monitoring plans will be established to track progress and to assess the implementation efforts. As previously stated, water quality standards could be attained in three of the subwatersheds using MPRs. However, in three other subwatersheds it was estimated that water quality standards could not be attained. MPRs may not be sufficient in subwatersheds where wildlife is a significant component or where very high reductions of fecal bacteria loads are required to meet water quality standards. In these cases, it is expected that the MPR scenario will be the first stage of TMDL implementation. Progress will be made through the iterative implementation process described above, and the situation will be reevaluated in the future.

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for fecal bacteria in the Liberty Reservoir watershed (MD basin number 02-13-09-07). Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to develop a TMDL for each impaired water quality limited segment (WQLS) on the Section 303(d) List, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Maryland Department of the Environment (MDE) has identified the tributaries of Liberty Reservoir in the State of Maryland's 303(d) List as impaired by fecal bacteria and impacts to biological communities (listed in 2002). The reservoir itself is not listed as impaired by fecal bacteria, but is listed as impaired by nutrients and sediments (listed in 1996) and by methylmercury (listed in 2002). The mainstem North Branch Patapsco River, mainstem West Branch Patapsco River and Cranberry Branch and its tributaries have been designated as Use IV-P (Recreational Trout Waters and Public Water Supply) waters. Roaring Run has been designated as Use III (Nontidal Cold Water). Beaver Run, Cooks Branch, East Branch Patapsco River, Keysers Run, Locust Run, Morgan Run, Norris Run and all their tributaries have been designated as Use III-P (Nontidal Cold Water and Public Water Supply). Liberty Reservoir and all remaining tributaries have been designated as Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply). See Code of Maryland Regulations (COMAR) 26.08.02.08K. Chromium and lead impairments (listed in 1996) have been removed from the 303(d) List through a water quality analysis (WQA) submitted to EPA in September 24, 2003. This document proposes to establish a TMDL for fecal bacteria in the Liberty Reservoir watershed that will allow for attainment of the beneficial use designation of primary water contact recreation. The listing for sediments, nutrients, methylmercury in fish tissue, and impacts to biological communities will be addressed separately at a future date. MDE monitored the Liberty Reservoir watershed from 2003 to 2004 for fecal bacteria. A data solicitation for fecal bacteria was conducted by MDE in 2003, and all readily available data from the past five years were considered.

Fecal bacteria are microscopic single-celled organisms (primarily fecal coliform and fecal streptococci) found in the wastes of warm-blooded animals. Their presence in water is used to assess the sanitary quality of water for body-contact recreation, for consumption of molluscan bivalves (shellfish), and for drinking water. Excessive amounts of fecal bacteria in surface water used for recreation are known to indicate an increased risk of pathogen-induced illness to humans. Infections due to pathogen-contaminated recreation waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases (US EPA 1986).

In 1986, EPA published "Ambient Water Quality Criteria for Bacteria," in which three indicator organisms were assessed to determine their correlation with swimming-associated illnesses. Fecal coliform, *E. coli* and enterococci were the indicators used in the analysis. Fecal coliform bacteria are a subgroup of total coliform bacteria and *E. coli* bacteria are a subgroup of fecal coliform bacteria. Most *E. coli* are harmless and are found in great quantities in the intestines of people and warm-blooded animals. However, certain pathogenic strains may cause illness. Enterococci are a subgroup of bacteria in the fecal streptococcus group. Fecal coliform, *E. coli* and enterococci can all be classified as fecal bacteria. The results of the EPA study demonstrated that fecal coliform showed less correlation to swimming-associated gastroenteritis than did either *E. coli* or enterococci.

Based on EPA's guidance (US EPA 1986), adopted by Maryland in 2004, the State has revised the bacteria water quality criteria and it is now based on water column limits for either *E. coli* or enterococci. Because multiple monitoring datasets are available within this watershed for various pathogen indicators, the general term "fecal bacteria" will be used to refer to the impairing substance throughout this document. The TMDL will be based on the pathogen indicator organisms specified in Maryland's current bacteria water quality criteria, either *E. coli* or enterococci. The indicator organism used in the Liberty Reservoir TMDL analysis was *E. coli.*

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Liberty Reservoir watershed is located in the Patapsco River basin of Maryland (See Figure 2.1.1) with a total drainage area of 104,800 acres (163.75 square miles). The majority of the watershed is located in Carroll County, MD with a portion in Baltimore County, MD (See Figure 2.1.1). The North Branch Patapsco River is the main tributary flowing into and out of Liberty Reservoir. The river's west branch begins north of Westminster and the east branch begins south of Manchester. Flowing south, the river becomes Liberty Reservoir, a drinking water supply for Carroll and Baltimore Counties, and Baltimore City. The major tributaries include Beaver Run, Morgan Run, Middle Run, and Little Morgan Run.

Land Use

The Liberty Reservoir watershed covers an area of 104,800 acres. Based on the 2002 Maryland Department of Planning (MDP) land use/land cover data, forest and agriculture land account for over 64% of the watershed and urban land accounts for 27% of the watershed. The land use percentage distribution is shown in Table 2.1.1, and spatial distributions for each land use are shown in Figure 2.1.2. Table 2.1.2 shows the land use percentage distribution for each subwatershed considered in the analysis. Note that the subwatersheds are identified by their MDE monitoring station, and are listed by flow from upstream to downstream. The sixth subwatershed encompasses all unmonitored areas downstream of the five monitoring stations, excepting the impoundment, and is identified as the Downstream Subwatershed.

Table 2.1.1: Land Use Distribution for the Liberty Reservoir Basin

Land Type	Area (acres)	Percentage (%)
Forest	32,043	31%
Agricultural	34,630	33%
Urban	27,879	27%
Pasture	6,895	7%
Water	3,353	3%
Total	**104,800**	**100**

Table 2.1.2: Land Use Distribution per Subwatershed in the Liberty Reservoir Basin

Station / Subwatershed	Land Use Area (%)				
	Agricultural	Forest	Urban	Pasture	Water
NPA0165 / North Branch Patapsco River	43%	23%	26%	7%	0%
BEA0016 / Beaver Run	33%	22%	40%	6%	0%
MDE0026 / Middle Run	33%	17%	38%	12%	0%
MOR0040 / Morgan Run	40%	32%	19%	9%	0%
LMR0015 / Little Morgan Run	28%	32%	33%	7%	0%
Downstream Subwatershed	19%	42%	25%	4%	10%

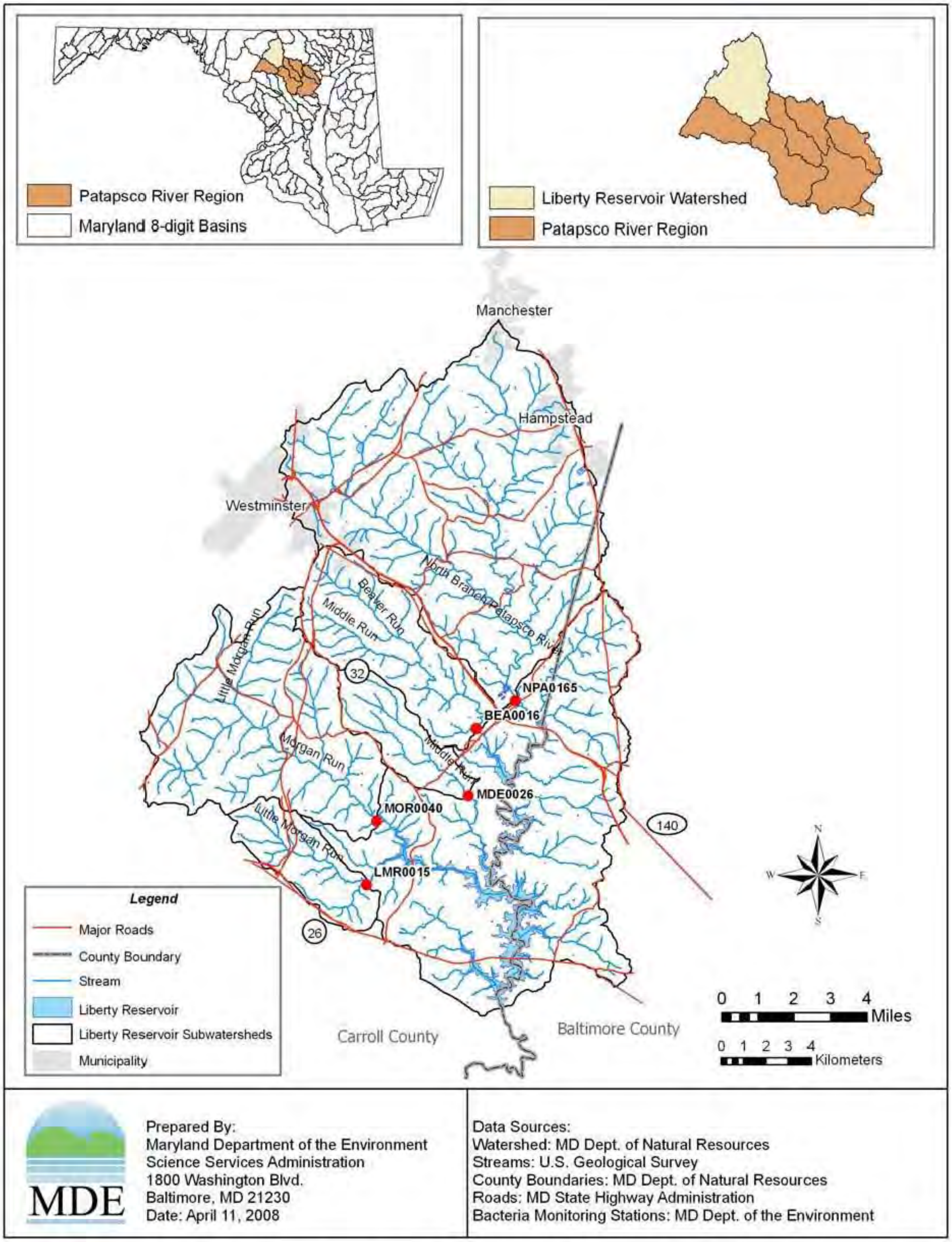

Figure 2.1.1: Location Map of the Area in the Liberty Reservoir Watershed

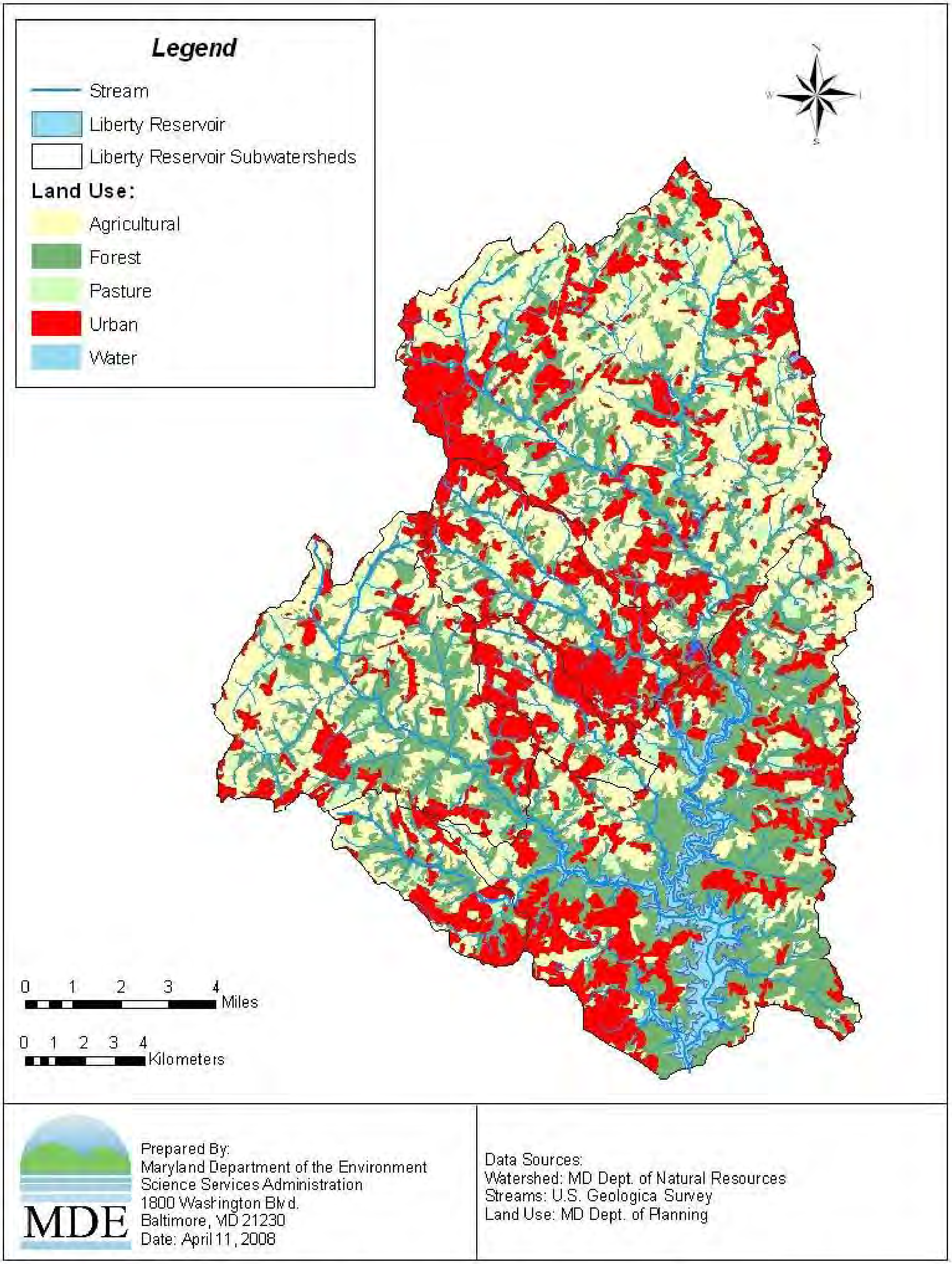

Figure 2.1.2: Land Use of the Liberty Reservoir Watershed

Population

The total population in the Liberty Reservoir watershed is estimated to be 62,584 people. Figure 2.1.3 depicts the population density in the region. The human population and the number of dwellings were estimated based on a weighted average from the 2000 Census GIS Block Groups and the 2002 MDP Land Use Land Cover. Since the boundaries of the watershed differ from the boundaries of the block groups, residential land use data were used to extract the necessary areas of the Census block groups. The MDP residential density designations shown in Table 2.1.3 were used for this estimation.

Table 2.1.3: Number of Dwellings Per Acre

Land Use Code	Dwellings Per Acre
11 Low Density Residential	1
12 Medium Density Residential	5
13 High Density Residential	8

Based on these densities and the population data from the census block groups the population for each subwatershed was estimated and is presented in Table 2.1.4.

Table 2.1.4: Total Population Per Subwatershed in the Liberty Reservoir Watershed

Tributary	Station	Population
North Branch Patapsco River	NPA0165	**22,929**
Beaver Run	BEA0016	8,104
Middle Run	MDE0026	2,869
Morgan Run	MOR0040	7,612
Little Morgan Run	LMR0015	3,758
Downstream Subwatershed		17,312
Total		**62,584**

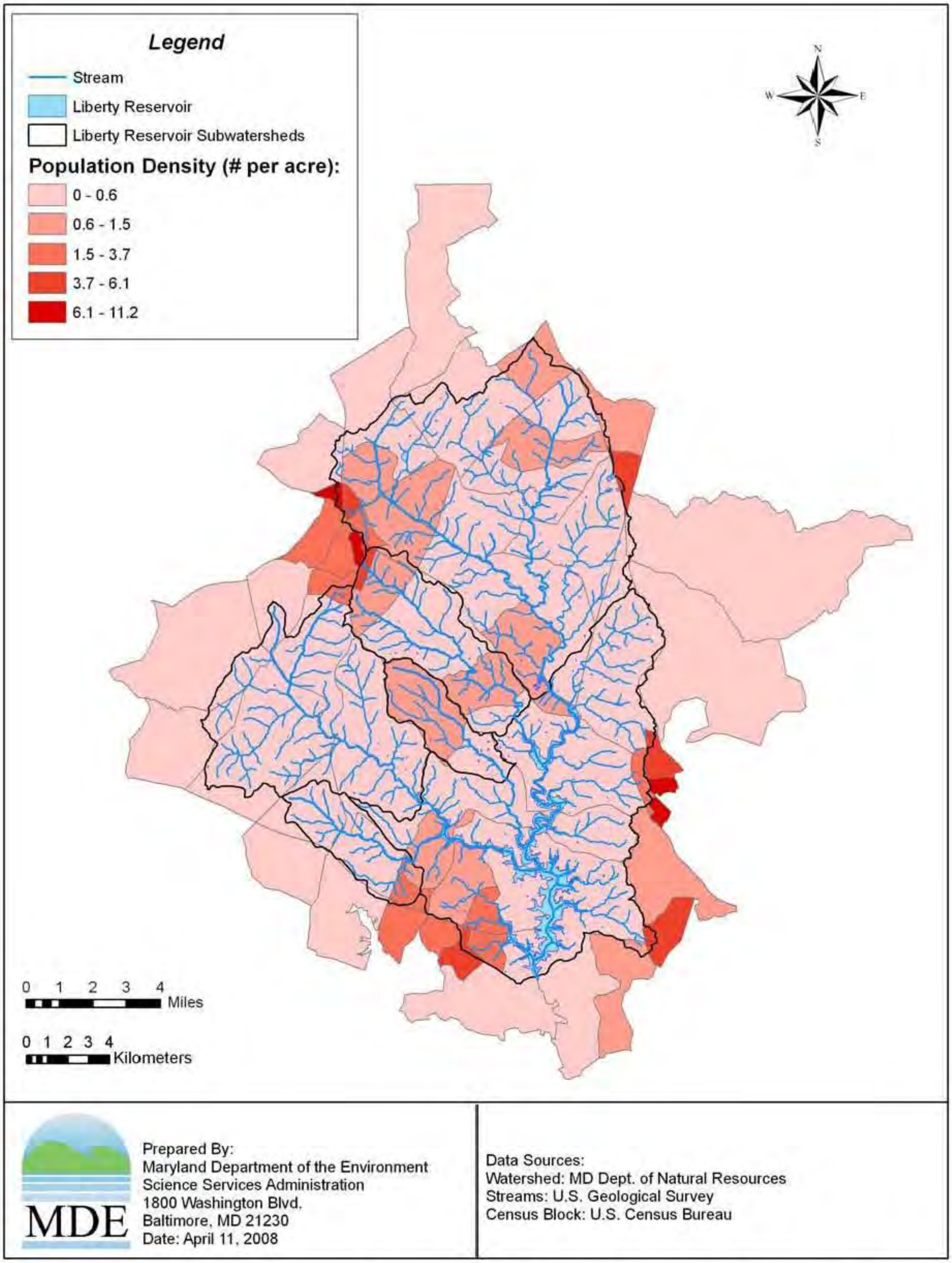

Figure 2.1.3: Population Density in the Liberty Reservoir Watershed

2.2 Water Quality Characterization

EPA's guidance document, "Ambient Water Quality Criteria for Bacteria" (1986), recommended that states use *E. coli* (for fresh water) or enterococci (for fresh or salt water) as pathogen indicators. Fecal bacteria, *E. coli*, and enterococci were assessed as indicator organisms for predicting human health impacts. A statistical analysis found that the highest correlation to gastrointestinal illness was linked to elevated levels of *E. coli* and enterococci in fresh water (enterococci in salt water).

As per EPA's guidance, Maryland has adopted the new indicator organisms, *E. coli* and enterococci, for the protection of public health in Use I, II, and IV waters. These bacteria listings were originally assessed using fecal coliform bacteria. The analysis was based on a geometric mean of the monitoring data, where the result had to be less than or equal to 200 MPN/100ml. From EPA's analysis (US EPA 1986), this fecal coliform geometric mean target equates to an approximate risk of 8 illnesses per 1,000 swimmers at fresh water beaches and 19 illnesses per 1,000 swimmers at marine beaches (enterococci only), which is consistent with MDE's revised Use I bacteria criteria. Therefore, the original 303(d) List fecal coliform listings can be addressed using the refined bacteria indicator organisms to ensure that risk levels are acceptable.

Bacteria Monitoring

Table 2.2.1 lists the historical monitoring data available for the Liberty Reservoir basin. MDE conducted bacteria monitoring at five stations in the Liberty Reservoir watershed from November 2003 through October 2004. Three United States Geological Survey (USGS) gauge stations, 01586000, 01586210 and 01586610, were used to derive the surface flow. The locations of these stations are shown in Tables 2.2.2 and 2.2.3 and in Figure 2.2.1. Observations recorded from the five MDE monitoring stations are provided in Appendix A.

Bacteria counts are highly variable which is typical due to the nature of bacteria and their relationship to flow. The E. coli counts for the five stations ranged between 10 and 24,190 MPN/100 ml.

Table 2.2.1: Historical Monitoring Data in the Liberty Reservoir Watershed

Organization	Date	Design	Summary
MDE	11/2003 through 10/2004	*E. coli*	5 stations 2 samples per month
MDE	11/2003 through 10/2004	BST (*Enterococcus)*	5 stations 1 sample per month

Table 2.2.2: Locations of MDE Monitoring Stations in the Liberty Reservoir Watershed

Tributary	Station Code	Observation Period	Total Observations	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
North Branch Patapsco River	NPA0016	2003-2004	24	39.501	-76.883
Beaver Run	BEA0016	2003-2004	24	39.489	-76.904
Middle Run	MDE0026	2003-2004	24	39.463	-76.908
Morgan Run	MOR0040	2003-2004	24	39.452	-76.955
Little Morgan Run	LMR0015	2003-2004	24	39.425	-76.961

Table 2.2.3: Location of USGS Gauging Stations in the Liberty Reservoir Watershed

Site Number	Observation Period Used	Total Observations	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
01586000	1988-2007	6,939	39.501	-76.885
01586210	1988-2007	6,927	39.487	-76.902
01586610	1988-2006	6,574	39.451	-76.953

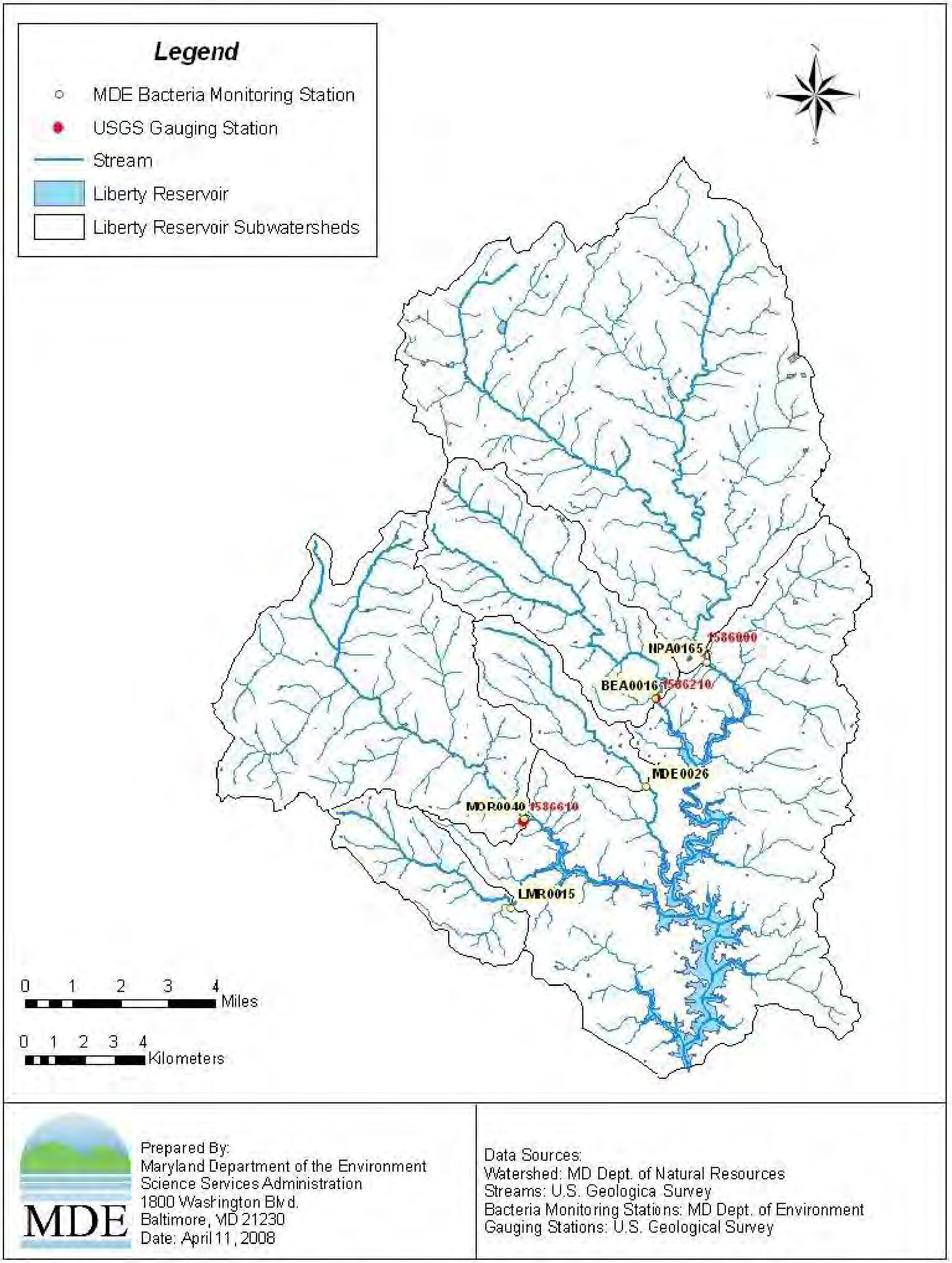

Figure 2.2.1: Monitoring Stations for the Liberty Reservoir Watershed

2.3 Water Quality Impairment

Designated Uses and Water Quality Standard

The Maryland water quality standards Surface Water Use Designation for the mainstem North Branch Patapsco River, mainstem West Branch Patapsco River and Cranberry Branch and it's tributaries is Use IV- P (Recreational Trout Waters and Public Water Supply). Roaring Run has been designated as Use III (Nontidal Cold Water). Beaver Run, Cooks Branch, East Branch Patapsco River, Keysers Run, Locust Run, Morgan Run, Norris Run and all their tributaries have been designated as Use III-P (Nontidal Cold Water and Public Water Supply). Liberty Reservoir and all remaining tributaries have been designated as Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply). See Code of Maryland Regulations (COMAR) 26.08.02.08K. The Liberty Reservoir watershed was listed on Maryland's 303(d) List in 2002 as impaired by fecal bacteria. Data collected by MDE from 2003 to 2004 showed high levels of fecal bacteria in five monitoring stations throughout the watershed, confirming the fecal bacteria impairment and resulting in the development of this fecal bacteria TMDL.

Water Quality Criteria

The State water quality standard for bacteria (*E. coli*) used in this study is as follows:

Table 2.3.1: Bacteria Criteria Values
(*Source: COMAR 26.08.02.03-3 Water Quality Criteria Specific to Designated Uses; Table 1)*

Indicator	Steady-state Geometric Mean Indicator Density
Freshwater	
E. coli	126 MPN/100 ml

Interpretation of Bacteria Data for General Recreational Use

The relevant portion (for freshwater) of the listing methodology pursuant to the 2006 Integrated 303(d) List for all Use Waters - Water Contact Recreation and Protection of Aquatic Life is as follows:

Recreational Waters

A steady-state geometric mean will be calculated with available data where there are at least five representative sampling events. The data shall be from samples collected during steady-state conditions and during the beach season (Memorial Day through Labor Day) to be representative of the critical condition. If the resulting steady-state geometric mean is greater than 126 *E. coli* MPN/100 ml in freshwater, the waterbody will be listed as impaired. If fewer than five representative sampling events for an area being assessed are available, data from the previous two years will be evaluated in the same way. The single sample maximum criterion applies only to beaches and is to be used for closure and advisory decisions based on short term exceedances of the geometric mean portion of the standard.

Water Quality Assessment

Bacteria water quality impairment in the Liberty Reservoir basin was assessed by comparing both the annual and the seasonal (May 1st –September 30th) steady-state geometric means of *E. coli* concentrations with the water quality criterion.

The steady-state condition is defined as unbiased sampling targeting average flow conditions and/or equally sampling or providing for unbiased sampling of high and low flows. The 1986 EPA criteria document assumed steady-state flow in determining the risk at various bacterial concentrations, and therefore the chosen criterion value also reflects steady-state conditions (US EPA 1986). The steady-state geometric mean condition can be estimated either by monitoring design or more practically by statistical analysis as follows:

1. A stratified monitoring design is used where the number of samples collected is proportional to the duration of high flows, mid flows and low flows within the watershed. This sample design allows a geometric mean to be calculated directly from the monitoring data without bias.

2. Routine monitoring typically results in samples from varying hydrologic conditions (i.e., high flows, mid flows and low flows) where the numbers of samples are not proportional to the duration of those conditions. Averaging these results without consideration of the sampling conditions results in a biased estimate of the steady-state geometric mean. The potential bias of the steady-state geometric means can be reduced by weighting the samples' results collected during high flow, mid flow and low flow regimes by the proportion of time each flow regime is expected to occur. This ensures that the high flow and low flow conditions are proportionally balanced.

3. If (1) the monitoring design was not stratified based on flow regime or (2) flow information is not available to weight the samples accordingly, then a geometric mean of sequential monitoring data can be used as an estimate of the steady-state geometric mean condition for the specified period.

A routine monitoring design was used to collect bacteria data for the Liberty Reservoir watershed. To estimate the steady-state geometric mean, the monitoring data were first reviewed by plotting the sample results versus their corresponding daily flow duration percentile. Graphs illustrating these results can be found in Appendix B.

To calculate the steady-state geometric mean with routine monitoring data, a conceptual model was developed by dividing the daily flow frequency for the stream segment into strata that are representative of hydrologic conditions. A conceptual continuum of flows is illustrated in Figure 2.3.1.

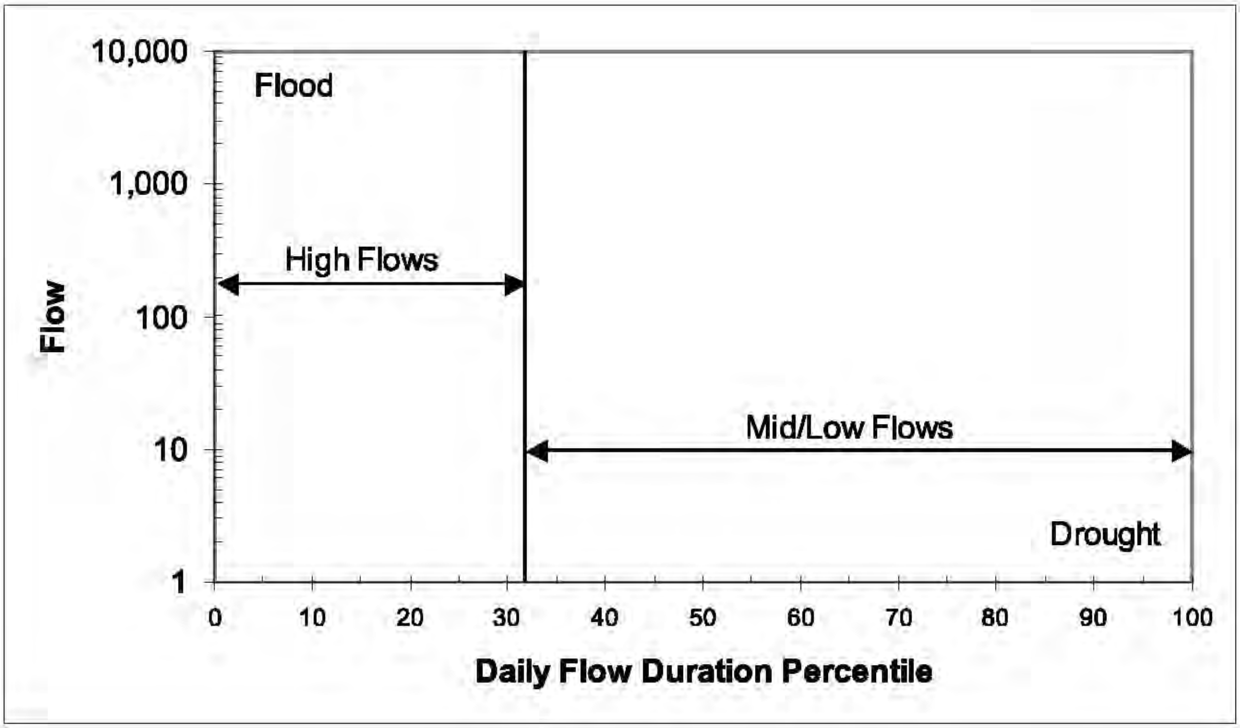

Figure 2.3.1: Conceptual Diagram of Flow Duration Zones

During high flows, a significant portion of the total stream flow is from surface flow contributions. Low flow conditions represent periods with minimal rainfall and surface runoff. There is typically a transitional mid flow period between the high and low flow durations, representative of varying contributions of surface flow inputs that result from differing rainfall volumes and antecedent soil moisture conditions. The division of the entire flow regime into strata enables the estimation of a less biased geometric mean from routine monitoring data that more closely approaches steady-state. Based on flow data of USGS gages 01586000, 01586210 and 01586610 it was determined that the long-term average daily flow corresponds to a daily flow duration of 32%. Hence for this analysis it is defined that flows greater than the 32 percentile flow represent high flows, and flows less than the 32 percentile flow represent mid/low flows. A detailed method of how the flow strata were defined is presented in Appendix B.

Factors for estimating a steady-state geometric mean are based on the frequency of each flow stratum. The weighting factor accounts for the proportion of time each flow stratum represents. The weighting factors for an average hydrological year used in the Liberty Reservoir TMDL analysis are presented in Table 2.3.2.

Table 2.3.2: Weighting Factors for Average Hydrology Year Used for Estimation of Geometric Means in the Liberty Reservoir Watershed

Flow Duration Zone	Duration Interval	Weighting Factor
High Flows	0 – 32%	0.317
Mid/Low Flows	32 – 100%	0.683

Bacteria enumeration results for samples within a specified stratum will receive their corresponding weighting factor. The steady-state geometric mean is calculated as follows:

$$M = \sum_{i=1}^{2} M_i * W_i \qquad (1)$$

where,

$$M_i = \frac{\sum_{j=1}^{n_i} \log_{10}(C_{i,j})}{n_i} \qquad (2)$$

M = log weighted mean
M_i = log mean concentration for stratum *i*
W_i = proportion of stratum *i*
$C_{i,j}$ = concentration for sample *j* in stratum *i*
n_i = number of samples in stratum

Finally, the steady-state geometric mean concentration is estimated using the following equation:

$$C_{gm} = 10^M \qquad (3)$$

where,

C_{gm} = Steady-state geometric mean concentration

Tables 2.3.3 and 2.3.4 present the maximum and minimum concentrations and the geometric means by stratum, and the overall steady-state geometric mean for the Liberty Reservoir subwatersheds for the annual and seasonal (May 1st – September 30th) periods. For the seasonal period, no samples fell in the high flow zone. As such, for the seasonal analysis, only the overall geometric mean for the period was applied. For the downstream subwatershed the average high and low flow geometric mean concentrations of the five upstream watersheds were applied to account for the unmonitored streams.

Table 2.3.3: Liberty Reservoir Basin Annual Steady-State Geometric Mean by Flow Stratum per Monitoring Station

Station / Tributary	Flow Stratum	Number of Samples	*E. coli* Minimum Concentration (MPN/100ml)	*E. coli* Maximum Concentration (MPN/100ml)	Annual Steady State Geometric Mean (MPN/100ml)	Annual Weighted Geometric Mean (MPN/100ml)
NPA0165 North Branch Patapsco River	**High**	14	10	9,800	107	236
	Low	10	70	5,800	339	
BEA0016 Beaver Run	**High**	13	20	930	82	153
	Low	11	20	4,400	204	
MDE0026 Middle Run	**High**	13	30	24,190	217	402
	Low	11	220	1,670	534	
MOR0040 Morgan Run	**High**	11	10	1,990	66	106
	Low	13	10	960	132	
LMR0015 Little Morgan Run	**High**	11	10	1,330	40	102
	Low	13	10	620	158	
Downstream Subwatershed	**High**	N/A			102	200
	Low				274	

Table 2.3.4: Liberty Reservoir Basin Seasonal Period (May 1 – September 30) Steady-State Geometric Mean per Monitoring Station

Station / Tributary	Number of Samples	*E. coli* Minimum Concentration (MPN/100ml)	*E. coli* Maximum Concentration (MPN/100ml)	Seasonal Steady State Geometric Mean (MPN/100ml)
NPA0165 North Branch Patapsco River	10	110	5,800	427
BEA0016 Beaver Run	10	60	4,400	278
MDE0026 Middle Run	10	250	1,670	607
MOR0040 Morgan Run	10	50	960	172
LMR0015 Little Morgan Run	10	50	510	200
Downstream Subwatershed	N/A			337

2.4 Source Assessment

<u>**Nonpoint Source Assessment**</u>

Nonpoint sources of fecal bacteria do not have one discharge point but occur over the entire length of a stream or waterbody. During rain events, surface runoff transports water and fecal bacteria over the land surface and discharges to the stream system. This transport is dictated by rainfall, soil type, land use, and topography of the watershed. Many types of nonpoint sources introduce fecal bacteria to the land surface, including the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. The deposition of non-human fecal bacteria directly to the stream occurs when livestock or wildlife have direct access to the waterbody. Nonpoint source contributions from human sources generally arise from failing septic systems and their associated drain fields or from leaking infrastructure (i.e., sewer systems).

The Liberty Reservoir watershed is serviced by both sewer systems and septic systems. Sewer systems are either present or planned in the towns of Westminster, Manchester, Hampstead, Eldersburg, and Reisterstown. The wastewater treatment plants (WWTP) for these towns do not fall within the Liberty Reservoir watershed. On-site disposal (septic) systems are located throughout the Liberty Reservoir basin. Table 2.4.1 presents the total number of septic systems per subwatershed. Figure 2.4.1 depicts the sewer service areas and the locations of the septic systems.

Table 2.4.1: Septic Systems per Subwatershed in the Liberty Reservoir Basin

Station / Subwatershed	Septic Systems (units)
NPA0165 / North Branch Patapsco River	4,739
BEA0016 / Beaver Run	1,980
MDE0026 / Middle Run	961
MOR0040 / Morgan Run	2,245
LMR0015 / Little Morgan Run	1,309
Downstream Subwatershed	4,085
Total	**15,319**

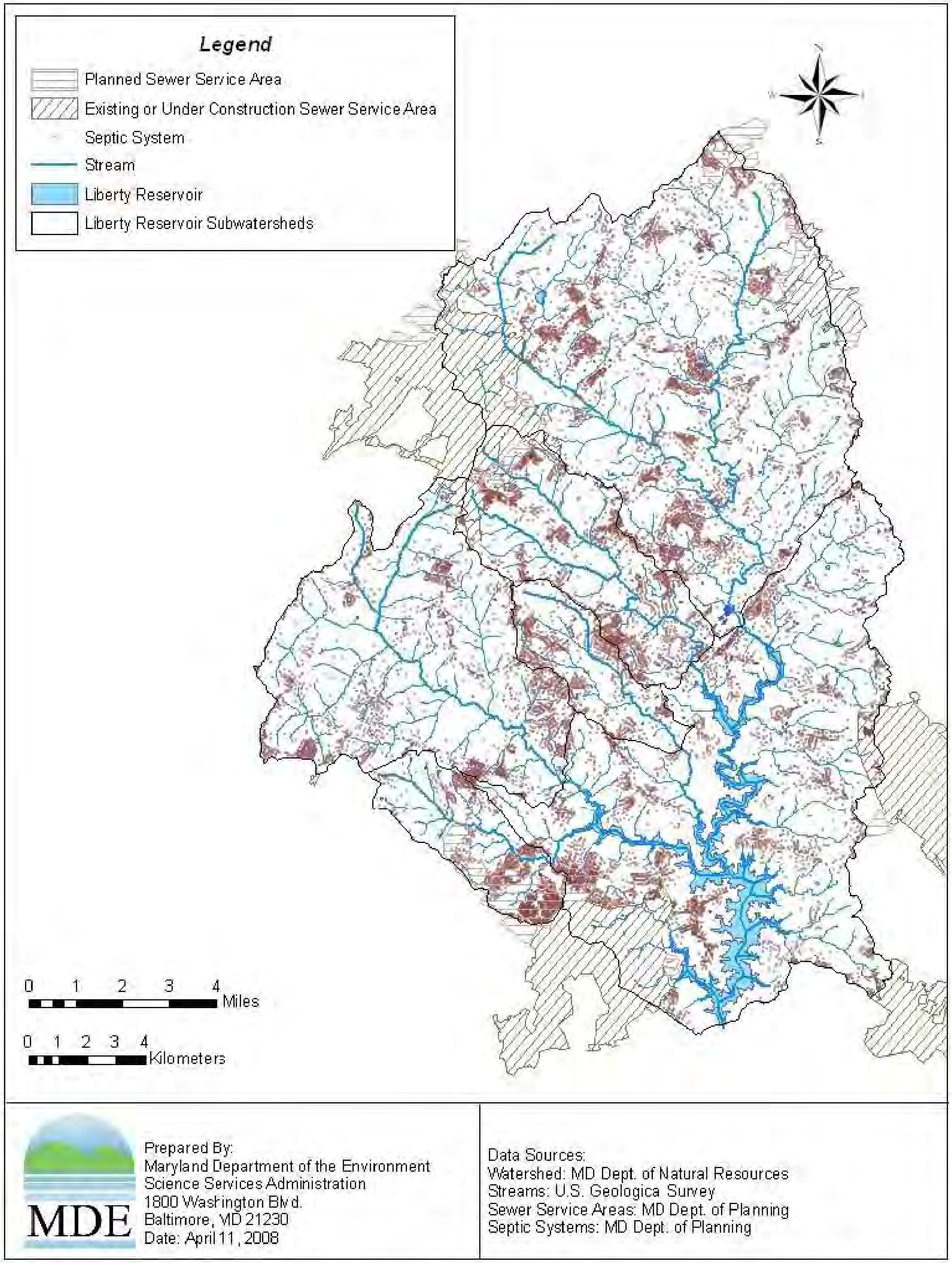

Figure 2.4.1: Septic Systems and Sewer Service Areas in the Liberty Reservoir Watershed

Point Source Assessment

There are two broad types of National Pollutant Discharge Elimination System (NPDES) permits considered in the analysis, individual and general. Both types of permits include industrial and municipal categories. Individual permits are issued for industrial and municipal WWTPs and Phase I municipal separate storm sewer systems (MS4s). MDE general permits have been established for surface water discharges from: Phase II and other MS4 entities; surface coal mines; mineral mines; quarries; borrow pits; ready-mix concrete; asphalt plants; seafood processors; hydrostatic testing of tanks and pipelines; marinas; concentrated animal feeding operations; and stormwater associated with industrial activities.

NPDES Regulated Stormwater

Bacteria sources associated with MS4s and other NPDES regulated stormwater discharges are considered point sources. Stormwater runoff is an important source of water pollution, including bacterial pollution. An MS4 is a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) designed or used for collecting or conveying stormwater and delivering it to a waterbody. MS4 programs are designed to reduce the amount of pollution that enters a waterbody from storm sewer systems to the maximum extent practicable.

The Liberty Reservoir basin is located in Baltimore and Carroll Counties, which both have individual NPDES Phase I MS4 permits. The municipalities of Westminster, Hampstead and Manchester are also covered by a general NPDES Phase II MS4 permit. Statements and information provided to MDE by the two Counties characterize much of the Liberty Reservoir watershed as essentially outside the reach of each County's stormwater system management plan (with the exception of the Westminster, Hampstead, and Manchester Phase II areas, and the Eldersburg Phase I urban area):

> "The Liberty Reservoir serves as a drinking water reservoir for the Baltimore metropolitan region. Predominate land use for the Baltimore County portion of the Liberty Reservoir watershed is forest cover. As such, an NPDES urban stormwater management plan is not required. Current zoning and reforestation activities will maintain the Liberty Reservoir watershed's undeveloped status." (Baltimore County 2006)
>
> "The Liberty Reservoir serves as a source of drinking water for the Baltimore metropolitan region. In addition, the Carroll County Commissioners also withdraw raw water from the Liberty Reservoir that is treated and distributed to a service area in the Eldersburg and Sykesville areas of Carroll County. As Liberty Lake lies upon the jurisdictional boundary between Carroll and Baltimore Counties, the western shoreline and the predominate watershed area is located within Carroll County.
>
> "The incorporated towns of Westminster, Hampstead and Manchester, as well as the Eldersburg area in southern Carroll County, along the MD Rt. 26 corridor, constitute the

predominate urban areas in Carroll County within the Liberty watershed. Westminster, Hampstead and Manchester are covered under the MS4 Phase II General Permit. The Eldersburg urban area is located along MD Rt. 26 west of Liberty Reservoir to a point just west of the MD Rt. 32 and east of the Piney Run Reservoir. It also extends somewhat north of MD Rt. 26, along MD Rt. 32 and south to the State lands around Springfield Hospital and the Patapsco Valley Park system and the incorporated Town of Sykesville. The approximate 3500 acre Eldersburg urban area is served by public water and sewer and is characterized by a mix of residential, commercial and light industrial development. The development within the Eldersburg area is generally served by a concentrated systemic urban storm sewer collection and management system. In addition, the Snowdens Run subwatershed is the subject of Carroll County's current watershed assessment and restoration planning efforts, as defined by the County's Phase I MS4 NPDES permit. Conversely, the remaining unincorporated lands within the Liberty watershed within Carroll County are generally characterized by agriculture or large lot residential uses with some light commercial and some isolated industrial land uses. Much of the development in those unincorporated areas is not served by an organized storm sewer management system, but rather by small fragmented systems that are often discharged through infiltration." (Carroll County, 2008)

MDE's Water Management Administration (WMA) has confirmed these characterizations of the watershed. Carroll County's Department of Planning has provided MDE with data and GIS files delineating the reach of the Phase II stormwater areas in Westminster, Manchester and Hampstead and the Phase I stormwater system in the Eldersburg urban area. Additionally, there are thirteen industrial stormwater permits in the watershed outside of these areas.

Sanitary Sewer Overflows

Sanitary Sewer Overflows (SSOs) occur when the capacity of a separate sanitary sewer is exceeded. There are several factors that may contribute to SSOs from a sewerage system, including pipe capacity, operations and maintenance effectiveness, sewer design, age of system, pipe materials, geology and building codes. SSOs are prohibited by the facilities' permits, and must be reported to MDE's Water Management Administration in accordance with COMAR 26.08.10 to be addressed under the State's enforcement program.

There were a total of six SSOs reported to MDE between November 2003 and October 2004 in the Liberty Reservoir watershed. Approximately 7,825 gallons of SSOs were discharged through various waterways (surface water, groundwater, sanitary sewers, etc.). Figure 2.4.2 shows the locations where SSOs occurred in the watershed between November 2003 and October 2004. Two of the events reported occurred at the same location.

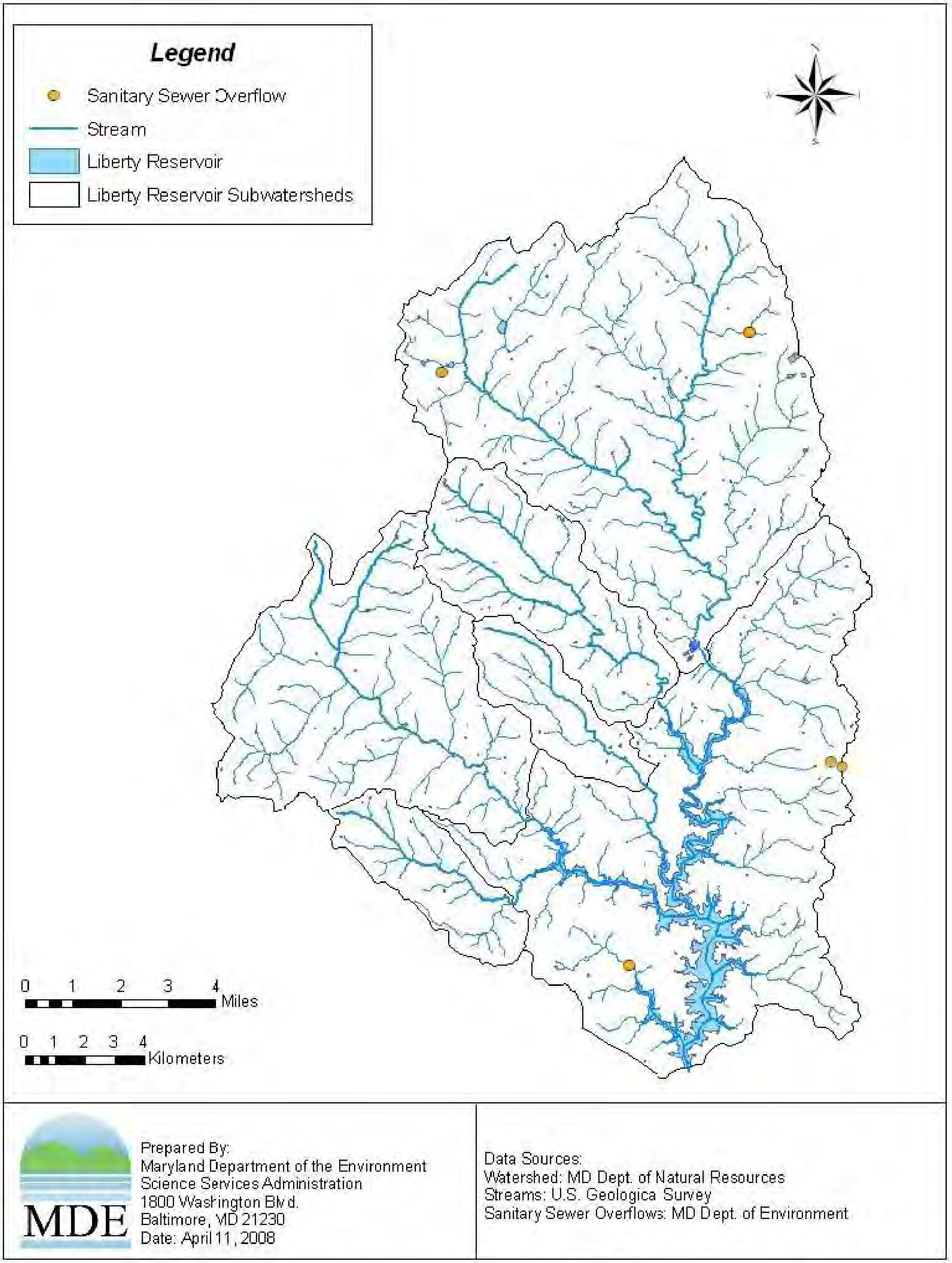

Figure 2.4.2: Sanitary Sewer Overflow Areas in the Liberty Reservoir Watershed

Municipal and Industrial Wastewater Treatment Plants (WWTPs)

Wastewater treatment plants are designed to treat wastewater before it is discharged to a stream or river. The goals of wastewater treatment are to protect the public health, protect aquatic life, and to prevent harmful substances from entering the environment.

Based on MDE's point source permitting information, there are two active industrial NPDES permitted point source facilities with permits regulating the discharge of fecal bacteria in the Liberty Reservoir watershed. These two facilities combined treat approximately 0.45 MGD (million gallons per day). There are no municipal facilities in the Liberty Reservoir watershed with NPDES permits regulating the discharge of fecal bacteria. Table 2.4.2 lists these facilities and Figure 2.4.3 shows their location in the watershed.

Table 2.4.2: NPDES Permit Holders Regulated for Fecal Bacteria Discharge in the Liberty Reservoir Watershed

Facility	NPDES Permit No.	County	Average Flow (MGD)	Fecal Coliform Concentration Annual AVG (MPN/100ml)	Fecal Coliform Load (Billion MPN/day)
Congoleum Corporation	MD0001384	Carroll	0.194	11.01	0.081
AG/GFI Hampstead, Inc	MD0001881	Carroll	0.255	2.00	0.019

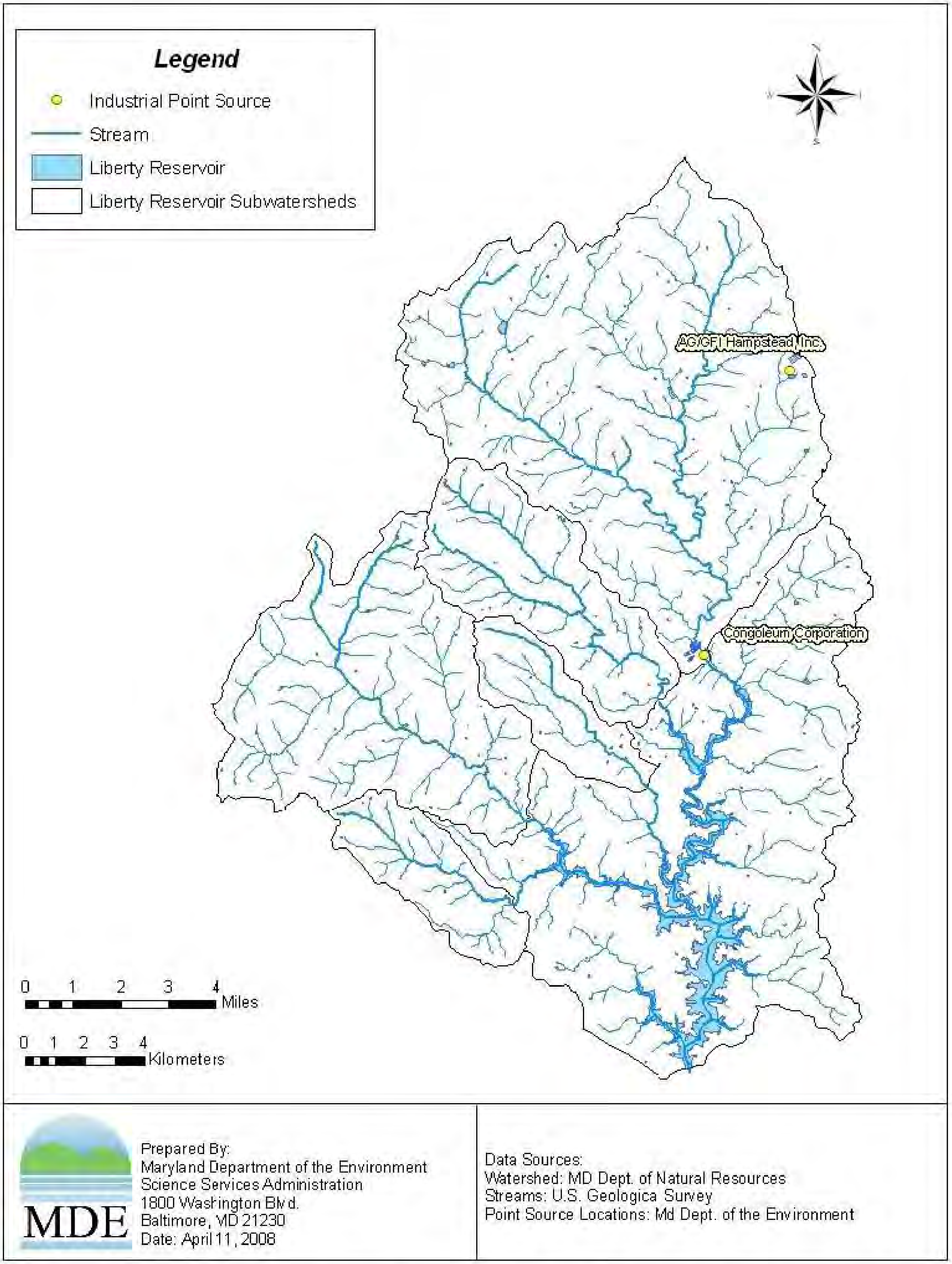

Figure 2.4.3: Permitted Point Sources Discharging Fecal Bacteria in the Liberty Reservoir Watershed

Bacteria Source Tracking

Bacteria source tracking (BST) was used to identify the relative contribution of different sources of bacteria to in-stream water samples. BST monitoring was conducted at five stations in the Liberty Reservoir watershed, where samples were collected once per month for a one-year duration. Sources are defined as domestic (pets and human associated animals), human (human waste), livestock (agricultural animals), and wildlife (mammals and waterfowl). To identify sources, samples are collected within the watershed from known fecal sources, and the patterns of antibiotic resistance of these known sources are compared to isolates of unknown bacteria from ambient water samples. Details of the BST methodology and data can be found in Appendix C.

An accurate representation of the expected contribution of each source at each station is estimated by using a stratified weighted mean of the identified sample results. The weighting factors are based on the $\log_{10}$ of the bacteria concentration and the percent of time that represents the high stream flow or low stream flow (see Appendix B). The procedure for calculating the stratified weighted mean of the sources per monitoring station is as follows:

1. Calculate the percentage of isolates per source per each sample date (S).
2. Calculate an initial weighted percentage (MS) of each source per flow strata (high/low). The weighting is based on the $\log_{10}$ bacteria concentration for the water sample.
3. Adjust the weighted percentage based on the classification of known sources.
4. The final weighted mean source percentage, for each source category, is based on the proportion of time in each flow duration zone.

The weighted mean for each source category is calculated using the following equations:

$$MS_l = \sum_{i=1}^{2} MS_{i,l} * W_i \qquad (4)$$

where,

$$MS_{i,l} = \sum_{k=1}^{5} \frac{A_{l,k} * IMS_{i,k}}{P_k} \qquad (5)$$

where,

$$IMS_{i,k} = \frac{\sum_{j=1}^{n_i} \log_{10}(C_{i,j}) * S_{i,j,k}}{\sum_{j=1}^{n_i} \log_{10}(C_{i,j})} \qquad (6)$$

and where,

MS_l = weighted mean proportion of isolates of source l
$MS_{i,l}$ = adjusted weighted mean proportion of isolates for source l in stratum i
$IMS_{i,k}$ = initial weighted mean proportion of isolates for source k in stratum i

W_i	= proportion covered by stratum i
$A_{l,k}$	= number of known source l isolates initially predicted as source k
P_k	= number of total known isolates initially predicted as source k
i	= stratum
j	= sample
k	= source category (1=human, 2=domestic, 3=livestock, 4=wildlife, 5=unknown)
l	= final source category (1=human, 2=domestic, 3=livestock, 4=wildlife)
$C_{i,j}$	= concentration for sample j in stratum i
$S_{i,j,k}$	= proportion of isolates for sample j, of source k in stratum i
n_i	= number of samples in stratum i

The complete distributions of the annual and seasonal periods source loads are listed in Tables 2.4.3 and 2.4.4. Details of the BST data and tables with the BST analysis results can be found in Appendix C. For the downstream subwatershed averages of the three upstream source percentages were used.

In the seasonal period, either no or fewer than five samples fell in the high flow category in these subwatersheds; therefore, a distribution by flow stratum was not calculated due to an insufficient number of samples. For the seasonal analysis, all samples between May 1st and September 30th were used to calculate an average seasonal distribution.

Table 2.4.3: Distribution of Fecal Bacteria Source Loads in the Liberty Reservoir Basin for the Average Annual Period

Station	Flow Stratum	% Domestic Animals	% Human	% Livestock	% Wildlife
NPA00165	High	8.1	16.8	50.9	24.2
	Low	15.3	37.3	17.9	29.5
	Weighted	13.0	30.8	28.4	27.8
BEA0016	High	17.7	24.2	34.7	23.4
	Low	12.3	31.5	25.0	31.2
	Weighted	14.0	29.2	28.1	28.8
MDE0026	High	17.9	24.5	33.8	23.8
	Low	18.1	27.1	25.9	28.9
	Weighted	18.1	26.3	28.4	27.3
MOR0040	High	14.7	12.1	38.7	34.5
	Low	16.2	25.6	26.9	31.3
	Weighted	15.7	21.3	30.7	32.3
LMR0015	High	12.2	4.4	49.9	33.5
	Low	16.5	11.6	35.0	36.8
	Weighted	15.1	9.3	39.8	35.8
Downstream Subwatershed	High	14.1	16.4	41.6	27.9
	Low	15.7	26.6	26.1	31.5
	Weighted	15.2	23.4	31.0	30.4

Table 2.4.4: Distribution of Fecal Bacteria Source Loads in the Liberty Reservoir Basin for the Seasonal Period (May 1st – September 30th)

Station	% Domestic Animals	% Human	% Livestock	% Wildlife
NPA0165	10.1	12.3	36.5	37.4
BEA0016	11.3	30.9	26.7	31.1
MDE0026	20.2	28.2	24.2	27.4
MOR0040	17.0	23.5	28.6	30.9
LMR0015	13.8	12.3	36.5	37.4
Downstream Subwatershed	14.5	24.9	29.6	31.0

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal bacteria TMDL set forth in this document is to establish the loading caps needed to ensure attainment of water quality standards in the Liberty Reservoir watershed. These standards are described fully in Section 2.3, "Water Quality Impairment."

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section provides an overview of the non-tidal fecal bacteria TMDL development, with a discussion of the many complexities involved in estimating bacteria concentrations, loads and sources. The second section presents the analysis framework and how the hydrological, water quality and BST data are linked together in the TMDL process. The third section describes the analysis for estimating a representative geometric mean fecal bacteria concentration and baseline loads. This analysis methodology is based on available monitoring data and is specific to a free-flowing stream system. The fourth section addresses the critical condition and seasonality. The fifth section presents the margin of safety. The sixth section discusses annual average TMDL loading caps and how maximum daily loads are estimated. The seventh section presents TMDL scenario descriptions. The eighth section presents the load allocations. Finally, in section nine, the TMDL equation is summarized.

To be most effective, the TMDL provides a basis for allocating loads among the known pollutant sources in the watershed so that appropriate control measures can be implemented and water quality standards achieved. By definition, the TMDL is the sum of the individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background sources. A margin of safety (MOS) is also included and accounts for the uncertainty in the analytical procedures used for water quality modeling, and the limits in scientific and technical understanding of water quality in natural systems. Although this formulation suggests that the TMDL be expressed as a load, the Code of Federal Regulations (40 CFR 130.2(i)) states that the TMDL can be expressed in terms of "mass per time, toxicity or other appropriate measure."

For many reasons, bacteria are difficult to simulate in water quality models. They reproduce and die off in a non-linear fashion as a function of many environmental factors, including temperature, pH, turbidity (UV light penetration) and settling. They occur in concentrations that vary widely (i.e., over orders of magnitude) and an accurate estimation of source inputs is difficult to develop. Finally, limited data are available to characterize the effectiveness of any program or practice at reducing bacteria loads (Schueler 1999).

Bacteria concentrations, determined through laboratory analysis of in-stream water samples for bacteria indicators (e.g., enterococci), are expressed in either colony forming units (CFU) or most probable number (MPN) of colonies. The first method (Method 1600) is a direct estimate of the bacteria colonies (US EPA 1985). The second method is a statistical estimate of the number of colonies (ONPG MUG Standard Method 9223B, AOAC 991.15). Sample results indicate the extreme variability in the total bacteria counts (see Appendix A). The distribution of the sample results tends to be lognormal, with a strong positive skew of the data. Estimating loads of constituents that vary by orders of magnitude can introduce much uncertainty and result in large confidence intervals around the final results.

Estimating bacteria sources can also be problematic due to the many assumptions required and the limited data available. Lack of specific numeric and spatial location data for several source categories, from failing septic systems to domestic animals, livestock, and wildlife populations, can create many potential uncertainties in traditional water quality modeling. For this reason, MDE applies an analytical method combined with the bacteria source tracking described above for the calculation of this TMDL.

4.2 Analytical Framework

This TMDL analysis uses flow duration curves to identify flow intervals that are used as indicators of hydrological conditions (i.e., annual average and critical conditions). This analytical method, combined with water quality monitoring data and BST, provides reasonable results (Cleland 2003), a better description of water quality than traditional water quality modeling, and also meets TMDL requirements.

In brief, baseline loads are estimated first for each subwatershed by using bacteria monitoring data and long-term flow data. These baseline loads are divided into four bacteria source categories using the results of BST analysis. Next, the percent reduction required to meet the water quality criterion in each subwatershed is estimated from the observed bacteria concentrations after determining the critical condition and accounting for seasonality. Critical condition and seasonality are determined by assessing annual and seasonal hydrological conditions for high flow and low flow periods. Finally, TMDLs for each subwatershed are estimated by applying these percent reductions.

Figure 4.2.1 illustrates how the hydrological (flow duration curve), water quality and BST data are linked together for the TMDL development.

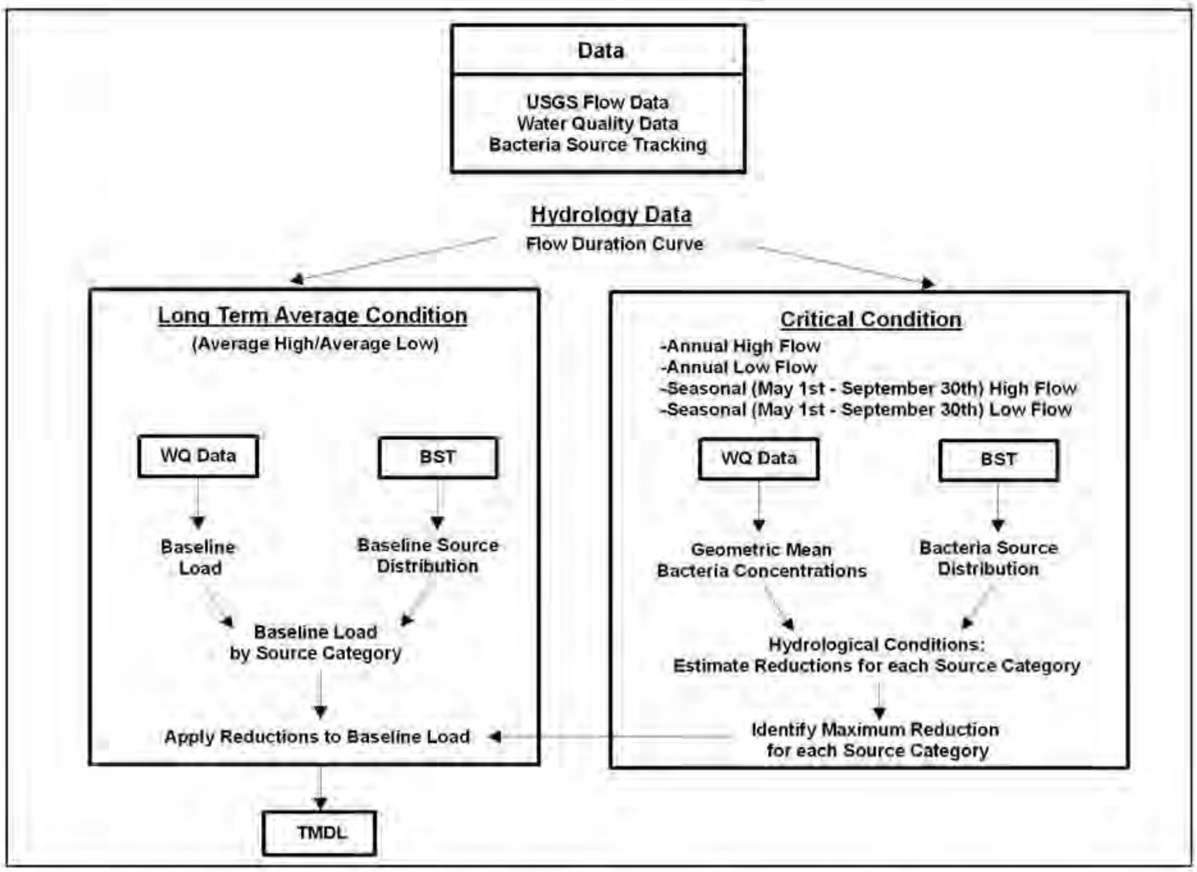

Figure 4.2.1: Diagram of the Non-Tidal Bacteria TMDL Analysis Framework

4.3 Estimating Baseline Loads

Baseline loads estimated in this TMDL analysis are reported as long-term average annual loads. These loads are estimated using geometric mean concentrations and bias correction factors (calculated from bacteria monitoring data) and daily average flows (estimated from long-term flow data).

The geometric mean concentration is calculated from the log transformation of the raw data. Statistical theory tells us that when back-transformed values are used to calculate average daily loads or total annual loads, the loads will be biased low (Richards 1998). To avoid this bias, a factor should be added to the log-concentration before it is back-transformed. There are several methods of determining this bias correction factor, ranging from parametric estimates resulting from the theory of the log-normal distribution to non-parametric estimates using a bias correction factor (Ferguson 1986; Cohn et al. 1989; Duan 1983). There is much literature on the applicability and results from these various methods with a summary provided in Richards (1998). Each has advantages and conditions of applicability. A non-parametric estimate of the bias correction factor (Duan 1983) was used in this TMDL analysis.

With calculated geometric means and arithmetic means for each flow stratum, the bias correction factors are estimated as follows:

$$F_{1i} = A_i/C_i \qquad (7)$$

where,

F_{1i} = bias correction factor for stratum *i*
A_i = long-term annual arithmetic mean for stratum *i*
C_i = long-term annual geometric mean for stratum *i*

Daily average flows are estimated for each flow stratum using the watershed area ratio approach, since nearby long-term monitoring data are available.

The loads for each stratum are estimated as follows:

$$L_i = Q_i * C_i * F_{1i} * F_2 \qquad (8)$$

where,

L_i = daily average load (Billion MPN/day) at monitoring station for stratum *i*
Q_i = daily average flow (cfs) for stratum *i*
C_i = geometric mean for stratum *i*
F_{1i} = bias correction factor for stratum *i*
F_2 = unit conversion factor (0.0245)

Finally, for each subwatershed, the baseline load is estimated as follows:

$$L = \sum_{i=1}^{2} L_i * W_i \qquad (9)$$

where,

L = daily average load at station (MPN/day)
W_i = proportion of stratum *i*

In the Liberty Reservoir watershed, weighting factors of 0.317 for high flow and 0.683 for low/mid flows were used to estimate the annual baseline load expressed as Billion MPN *E. coli*/year.

Estimating Subwatershed Loads

Subwatersheds with more than one monitoring station are subdivided into unique watershed segments, thus allowing individual load and reduction targets to be determined for each. In the Liberty Reservoir watershed the portion of the watershed downstream of the five monitoring stations, as listed in Table 4.3.1, is referred to as the Downstream Subwatershed. This identification represents only the area and load downstream of the five stations.

Table 4.3.1: Subdivided Watersheds in the Liberty Reservoir Watershed

Subwatershed	Upstream Station(s)
Downstream Subwatershed	NPA0165, BEA0016, MDE0026, MOR0040, LMR0015

Bacteria loads from this subwatershed are joined by loads from the upstream subwatersheds to result in the concentration that would be measured downstream. However, for the purposes of this TMDL, the downstream bacteria concentration is assigned as the average of the five upstream concentrations and is assumed to be representative of the downstream subwatershed. The bacteria source distribution for the downstream subwatershed is also assigned as the average of the BST analysis results of the five upstream stations.

Results of the baseline load calculations are presented in Table 4.3.2. A summary of the baseline loads is given in Table 4.3.3.

Table 4.3.2: Baseline Load Calculations

Subwatershed	Area (mi^2)	High Flow		Low Flow		Baseline *E. coli* Load (Billion MPN/year)
		Average Flow (cfs)	*E. coli* Concentration. (MPN/100ml)	Average Flow (cfs)	*E. coli* Concentration (MPN/100ml)	
NPA0165	56.0	136.7	107	35.9	339	525,154
BEA0016	14.1	33.9	82	9.3	204	49,032
MDE0026	6.1	14.8	217	4.0	534	103,531
MOR0040	28.1	73.8	66	18.0	132	76,369
LMR0015	7.1	18.6	40	4.6	158	15,078
Downstream Subwatershed	52.4	127.8	102	33.6	274	314,084

Table 4.3.3: Liberty Reservoir Baseline Loads Summary

MD 8-Digit Liberty Reservoir Fecal Bacteria Baseline Loads (Billion MPN *E. coli*/year)						
Total Baseline Load	=	**Nonpoint Source BL**	+	**Stormwater BL**	+	**WWTP BL**
1,083,248	=	979,511	+	102,692	+	1,045

4.4 Critical Condition and Seasonality

Federal regulations (40 CFR 130.7(c)(1)) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable.

For this TMDL the critical condition is determined by assessing annual and seasonal hydrological conditions for high flow and low flow periods. Seasonality is assessed as the time period when water contact recreation is expected, specifically May 1st through September 30th. For this TMDL analysis, the average hydrological condition over a 20-year period has been estimated as 32% high flow and 68% low flow as defined in Appendix B. Using the definition of a high flow condition as occurring when the daily flow duration interval is less than 32% and a low flow condition as occurring when the daily flow duration interval is greater than 32%, critical hydrological condition can be estimated by the percent of high or low flows during a specific period.

Using long-term flow data from USGS stations 01586000, 01586210, and 01586610, critical condition and seasonality has been determined by assessing various hydrological conditions to account for seasonal and annual averaging periods. The four conditions listed in Table 4.4.1 were used to account for the annual, critical, and seasonal conditions.

Table 4.4.1: Hydrological Conditions Used to Account for Critical Condition and Seasonality

USGS Gage	Hydrological Condition		Averaging Period	Water Quality Data Used	Fraction High Flow	Fraction Low Flow	Condition Period
01586000	Annual	Average	365 days	All	0.32	0.68	Long Term Average
		Wet	365 days	All	0.778	0.223	May 2003 – May 2004
		Dry	365 days	All	0.019	0.981	Sept. 2001 – Sept. 2002
	Seasonal	Average	May 1st – Sept. 30th	May 1st – Sept. 30th	N/A	N/A	Long-Term Average For May – Sept. Period
01586210	Annual	Average	365 days	All	0.32	0.68	Long Term Average
		Wet	365 days	All	0.805	0.196	Jan. 1997 – Jan. 1998
		Dry	365 days	All	0.017	0.984	Sept. 2001 – Sept. 2002
	Seasonal	Average	May 1st – Sept. 30th	May 1st – Sept. 30th	N/A	N/A	Long-Term Average For May – Sept. Period
01586610	Annual	Average	365 days	All	0.32	0.68	Long Term Average
		Wet	365 days	All	0.934	0.066	Jan. 1996 – Jan. 1997
		Dry	365 days	All	0.011	0.989	Sept. 2001 – Sept. 2002
	Seasonal	Average	May 1st – Sept. 30th	May 1st – Sept. 30th	N/A	N/A	Long-Term Average For May – Sept. Period

The critical condition requirement is met by determining the maximum reduction per bacteria source that satisfies all hydrological conditions and meets the water quality standard, thereby minimizing the risk to water contact recreation. It is assumed that the reduction applied to a bacteria source category will be constant through all conditions.

The bacteria monitoring data for the five stations in the Liberty Reservoir basin cover a sufficient temporal span (at least one year) to estimate annual conditions. However, sufficient data were not available for the seasonal period to consider high flow and low flow conditions. Since all samples of the seasonal period were taken during low flow, a geometric mean cannot be established for the high flow condition. Therefore an average geometric mean and average flow were used for the seasonal analysis.

The reductions of fecal bacteria required to meet water quality standards in each subwatershed of the Liberty Reservoir basin are shown in Table 4.4.2.

Table 4.4.2: Required Fecal Bacteria Reductions (by Hydrological Condition per Subwatershed) to Meet Water Quality Standards

Station / Tributary	Hydrological Condition		Domestic Animals %	Human %	Livestock %	Wildlife %
NPA0165 North Branch Patapsco River	Annual	Average	10.1	95.0	63.7	0.0
		Wet	0.0	82.0	0.0	0.0
		Dry	14.4	98.0	91.0	0.0
	Seasonal	Average	98.0	98.0	98.0	4.9
	Maximum Source Reduction		**98.0**	**98.0**	**98.0**	**4.9**
BEA0016 Beaver Run	Annual	Average	0.0	74.6	0.0	0.0
		Wet	0.0	0.0	0.0	0.0
		Dry	47.4	95.0	19.2	0.0
	Seasonal	Average	73.9	95.0	72.3	0.0
	Maximum Source Reduction		**73.9**	**95.0**	**72.3**	**0.0**
MDE0026 Middle Run	Annual	Average	91.9	98.0	98.0	0.0
		Wet	68.0	98.0	52.6	0.0
		Dry	98.0	98.0	98.0	26.0
	Seasonal	Average	98.0	98.0	98.0	33.3
	Maximum Source Reduction		**98.0**	**98.0**	**98.0**	**33.3**
MOR0040 Morgan Run	Annual	Average	0.0	0.0	0.0	0.0
		Wet	0.0	0.0	0.0	0.0
		Dry	0.0	34.9	0.0	0.0
	Seasonal	Average	12.5	95.0	21.0	0.0
	Maximum Source Reduction		**12.5**	**95.0**	**21.0**	**0.0**
LMR0015 Little Morgan Run	Annual	Average	0.0	0.0	0.0	0.0
		Wet	0.0	0.0	0.0	0.0
		Dry	13.3	95.0	28.4	0.0
	Seasonal	Average	25.8	95.0	68.5	0.0
	Maximum Source Reduction		**25.8**	**95.0**	**68.5**	**0.0**
Downstream Subwatershed	Annual	Average	18.1	95.0	53.2	0.0
		Wet	0.0	36.9	0.0	0.0
		Dry	61.2	95.0	75.0	0.0
	Seasonal	Average	75.9	98.0	98.0	0.0
	Maximum Source Reduction		**75.9**	**98.0**	**98.0**	**0.0**

4.5 Margin of Safety

A margin of safety (MOS) is required as part of this TMDL in recognition of the many uncertainties in the understanding and simulation of bacteriological water quality in natural systems and in statistical estimates of indicators. As mentioned in Section 4.1, it is difficult to estimate stream loadings for fecal bacteria due to the variation in loadings across sample locations and time. Load estimation methods should be both precise and accurate to obtain the true estimate of the mean load. Refined precision in the load estimation is due to using a stratified approach along the flow duration intervals, thus reducing the variation in the estimates. Moreover, Richards (1998) reports that averaging methods are generally biased, and the bias increases as the size of the averaging window increases. Finally, accuracy in the load estimation is based on minimal bias in the final result when compared to the true value.

Based on EPA guidance, the MOS can be achieved through two approaches (US EPA 1991a). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = LA + WLA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis. The second approach was used for this TMDL by estimating the loading capacity of the stream based on a reduced (more stringent) water quality criterion concentration. The *E. coli* water quality criterion concentration was reduced by 5%, from 126 *E. coli* MPN/100ml to 119.7 *E. coli* MPN/100ml.

4.6 Scenario Descriptions

Source Distribution

The final bacteria source distribution and corresponding baseline loads are derived from the source proportions listed in Table 2.4.3. The source distribution and baseline loads used in the TMDL scenarios are presented in Table 4.6.1.

Table 4.6.1: Bacteria Source Distributions and Corresponding Baseline Loads Used in the Annual Average TMDL Analysis

Subwatershed	Domestic		Human		Livestock		Wildlife		Total Load (Billion *E. coli* MPN/year)
	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	
NPA0165	13.0	68,231	30.8	161,843	28.4	149,083	27.8	145,997	525,154
BEA0016	14.0	6,873	29.2	14,302	28.0	13,754	28.8	14,103	49,032
MDE0026	18.1	18,705	26.3	27,221	28.4	29,386	27.3	28,219	103,531
MOR0040	15.7	12,025	21.3	16,276	30.7	23,422	32.3	24,646	76,369
LMR0015	15.1	2,283	9.3	1,407	39.8	5,994	35.8	5,394	15,078
Downstream Subwatershed	15.2	47,718	23.4	73,448	31.0	97,521	30.4	95,397	314,084

First Scenario: Fecal Bacteria Practicable Reduction Targets

The maximum practicable reduction (MPR) for each of the four source categories is listed in Table 4.6.2. These values are based on review of the available literature and best professional judgment. It is assumed that human sources would potentially have the highest risk of causing gastrointestinal illness and therefore should have the highest reduction. If a domestic WWTP is located in the upstream watershed, this is considered in the MPR so as to not violate the permitted loads. The domestic animal category includes sources from pets (e.g., dogs) and the MPR is based on an estimated success of education and outreach programs.

Table 4.6.2: Maximum Practicable Reduction Targets

Max Practicable Reduction per Source	Human	Domestic	Livestock	Wildlife
	95%	75%	75%	0%
Rationale	(a) Direct source inputs. (b) Human pathogens more prevalent in humans than animals. (c) Enteric viral diseases spread from human to human.[1]	Target goal reflects uncertainty in effectiveness of urban BMPs[2] and is also based on best professional judgment	Target goal based on sediment reductions from BMPs[3] and best professional judgment	No programmatic approaches for wildlife reduction to meet water quality standards. Waters contaminated by wild animal wastes offer a public health risk that is orders of magnitude less than that associated with human waste.[4]

[1]Health Effects Criteria for Fresh Recreational Waters. EPA-600/1-84-004. U.S. Environmental Protection Agency, Washington, DC. EPA. 1984.
[2]Preliminary Data Summary of Urban Storm Water Best Management Practices. EPA-821-R-99-012. U.S. Environmental Protection Agency, Washington, DC. EPA. 1999.
[3]Agricultural BMP Descriptions as Defined for The Chesapeake Bay Program Watershed Model. Nutrient Subcommittee Agricultural Nutrient Reduction Workshop. EPA. 2004.
[4]Environmental Indicators and Shellfish Safety. 1994. Edited by Cameron, R., Mackeney and Merle D. Pierson, Chapman & Hall.

As previously stated, these maximum practicable reduction targets are based on the available literature and best professional judgment. There is much uncertainty with estimated reductions from best management practices (BMP). The BMP efficiency for bacteria reduction ranged from –6% to +99% based on a total of 10 observations (US EPA 1999). The MPR to agricultural lands was based on sediment reductions identified by EPA (US EPA 2004).

The practicable reduction scenario was developed based on an optimization analysis whereby a subjective estimate of risk was minimized and constraints were set on maximum reduction and allowable background conditions. Risk was defined on a scale of one to five, where it was assumed that human sources had the highest risk (5), domestic animals and livestock next (3), and wildlife the lowest (1) (See Table 4.6.2). The model was defined as follows:

$$\text{Risk Score} = \text{Min} \sum_{i=1}^{4} P_j * W_j \qquad (9)$$

where,

$$P_j = \frac{(1-R_i) * Pb_j}{1-TR} \qquad (10)$$

and,

$$TR = \frac{C - C_{cr}}{C} \qquad (11)$$

Therefore the risk score can be represented as:

$$Risk\ Score = Min \sum_{i=1}^{4} \left[\frac{(1 - R_j) * Pb_j}{(1 - \frac{C - Ccr}{C})} * W_j \right] \qquad (12)$$

where,

i	= hydrological condition
j	= bacteria source category =human, domestic animal, livestock and wildlife
P_j	= % of each source category (human, domestic animals, livestock and wildlife) in final allocation
W_j	= weight of risk per source category = 5, 3 or 1
R_j	= percent reduction applied by source category (human, domestic animals, livestock and wildlife) for the specified hydrological condition (variable)
Pb_j	= original (baseline) percent distribution by source category (variable)
TR	= total reduction (constant within each hydrological condition) = Target reduction
C	= in-stream concentration
Ccr	= water quality criterion

The model is subject to the following constraints:

$$C = Ccr$$
$$0 \leq R_{human} \leq 95\%$$
$$0 \leq R_{pets} \leq 75\%$$
$$0 \leq R_{livestock} \leq 75\%$$
$$R_{wildlife} = 0$$
$$P_j \geq 1\%$$

In three subwatersheds, the constraints of this scenario could be satisfied; however, in three subwatersheds the constraints of this scenario could not be satisfied indicating there was not a practicable solution. A summary of the first scenario analysis results is presented in Table 4.6.3.

Table 4.6.3: Maximum Practicable Reduction Scenario Results

Subwatershed	Applied Reductions				Total Reduction %	Target Reduction %	Achievable?
	Domestic Animals %	Human %	Livestock %	Wildlife %			
NPA0165	75.0	95.0	75.0	0.0	60.3	72.1	No
BEA0016	73.9	95.0	72.3	0.0	58.3	58.3	Yes
MDE0026	75.0	95.0	75.0	0.0	59.8	80.4	No
MOR0040	12.5	95.0	21.0	0.0	28.6	28.6	Yes
LMR0015	25.8	95.0	68.5	0.0	40.0	40.0	Yes
Downstream Subwatershed	75.0	95.0	75.0	0.0	56.9	64.9	No

Second Scenario: Fecal Bacteria Reductions Higher Than MPRs

The TMDL must specify load allocations that will meet the water quality standards. In the practicable reduction targets scenario, three of the six subwatersheds could meet water quality standards based on MPRs. Therefore, this second scenario was applied only to subwatersheds NPA0165, MDE0026, and the downstream subwatershed where water quality standards could not be met by applying the MPRs.

To further develop the TMDL, a second scenario was analyzed in which the constraints on the MPRs were relaxed. In these subwatersheds, the maximum allowable reduction was increased to 98% for all sources, including wildlife. A similar optimization procedure as before was used to minimize risk. Again, the objective is to minimize the sum of the risk for all conditions while meeting the scenario reduction constraints. The model was defined in the same manner as considered in the practicable reduction scenario but subject to the following constraints:

$$
\begin{aligned}
C &= Ccr \\
0 \leq R_{human} &\leq 98\% \\
0 \leq R_{pets} &\leq 98\% \\
0 \leq R_{livestock} &\leq 98\% \\
0 \leq R_{wildlife} &\leq 98\% \\
P_j &\geq 1\%
\end{aligned}
$$

A summary of the results of this second scenario analysis is presented in Table 4.6.4.

Table 4.6.4: Reduction Results Based on Optimization Model Allowing up to 98% Reduction of All Sources

Subwatershed	Applied Reductions				Total Reduction %	Target Reduction %
	Domestic %	Human %	Livestock %	Wildlife %		
NPA0165	98.0	98.0	98.0	4.9	72.1	72.1
BEA0016	73.9	95.0	72.3	0.0	58.3	58.3
MDE0026	98.0	98.0	98.0	33.3	80.4	80.4
MOR0040	12.5	95.0	21.0	0.0	28.6	28.6
LMR0015	25.8	95.0	68.5	0.0	40.0	40.0
Downstream Subwatershed	75.9	98.0	98.0	0.0	64.9	64.9

4.7 TMDL Loading Caps

The TMDL loading cap is an estimate of the assimilative capacity of the monitored watershed. Estimation of the TMDL requires knowledge of how bacteria concentrations vary with flow rate or the flow duration interval. This relationship between concentration and flow is established using the strata defined by the flow duration curve.

The TMDL loading caps are provided in billion MPN *E. coli*/day. These loading caps are for the five subwatersheds located upstream of their respective monitoring stations (NPA0165, BEA0016, MDE0026, MOR0040, and LMR0015) as well as the one downstream watershed.

Annual Average TMDL Loading Caps

As explained in the sections above, the annual average TMDL loading caps are estimated by first determining the baseline or current condition loads for each subwatershed and the associated geometric mean from the available monitoring data. This annual average baseline load is estimated using the geometric mean concentration and the long-term annual average daily flow for each flow stratum. The loads from these two strata are then weighted to represent average conditions (see Table 4.3.1), based on the proportion of each stratum, to estimate the total long-term loading rate.

Next, the percent reduction required to meet the water quality criterion is estimated from the observed bacteria concentrations accounting for the critical conditions (See Section 4.4). A reduction in concentration is proportional to a reduction in load; thus the TMDL is equal to the current baseline load multiplied by one minus the required reduction. This reduction, estimated as explained in Section 4.4, represents the maximum reduction per source that satisfies all hydrological conditions in each subwatershed, and that is required to meet water quality standards.

$$\text{TMDL Loading Cap} = L_b * (1 - R) \qquad (13)$$

where,

L_b = current or baseline load estimated from monitoring data
R = reduction required from baseline to meet water quality criterion.

The annual average bacteria TMDL loading caps for the subwatersheds are shown in Tables 4.7.1 and 4.7.2.

Table 4.7.1: Annual Average TMDL Loading Caps

Subwatershed	*E. coli* Baseline Load (Billion MPN/year)	Long-Term Average *E. coli* TMDL Load (Billion MPN/year)	% Target Reduction
NPA0165 North Branch Patapsco River	525,154	146,397	72.1
BEA0016 Beaver Run	49,032	20,425	58.3
MDE0026 Middle Run	103,531	20,333	80.4
MOR0040 Morgan Run	76,369	54,496	28.6
LMR0015 Little Morgan Run	15,078	9,044	40.0
Downstream Subwatershed	314,084	110,313	64.9
Total	**1,083,248**	**361,008**	**66.7**

Table 4.7.2: Annual Average TMDL Loading Caps by Source Category

Subwatershed	Domestic		Human		Livestock		Wildlife		Total Load (Billion *E. coli* MPN/year)
	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	
NPA0165 North Branch Patapsco River	0.9	1,364	2.2	3,237	2.0	2,982	94.8	138,814	146,397
BEA0016 Beaver Run	8.8	1,797	3.5	715	18.7	3,810	69.0	14,103	20,425
MDE0026 Middle Run	1.8	374	2.7	545	2.9	588	92.6	18,826	20,333
MOR0040 Morgan Run	19.3	10,526	1.5	814	34.0	18,510	45.2	24,646	54,496
LMR0015 Little Morgan Run	18.7	1,693	0.8	70	20.9	1,889	59.6	5,392	9,044
Downstream Subwatershed	10.4	11,496	1.3	1,469	1.8	1,950	86.5	95,398	110,313

Maximum Daily Loads

Recent EPA guidance (US EPA 2006a) recommends that maximum daily load (MDL) expressions of long-term annual average TMDLs should also be provided as part of the TMDL analysis and report. Selection of an appropriate method for translating a TMDL based on a longer time period into one using a daily time period requires decisions regarding 1) the level of resolution, and 2) the level of protection. The level of resolution pertains to the amount of detail used in specifying the maximum daily load. The level of protection represents how often the maximum daily load (MDL) is expected to be exceeded. Draft EPA/TetraTech guidance on daily loads (Limno-Tech 2007) provides three categories of options for both level of resolution and level of protection, and discusses these categories in detail.

For the Liberty Reservoir watershed MDLs, a "representative daily load" option was selected as the level of resolution, and a value "that will be exceeded with a pre-defined probability" was selected as the level of protection. In these options, the MDLs are two single daily loads that correspond to the two flow strata, with an upper bound percentile that accounts for the variability of daily loads. The upper bound percentile and the MDLs were estimated following EPA's "*Technical Support Document for Water Quality-Based Toxics Control*" (1991 TSD) (US EPA 1991); and "*Approaches For Developing a Daily Load Expression for TMDLs Computed for Longer Term Averages*" (US EPA 2006b).

There are three steps to the overall process of estimating these MDLs. First, all the data available from each monitoring station are examined together by stratum and the percentile rank of the highest observed concentration (for each stratum at each station) is computed. The highest computed percentile rank is the upper bound percentile to be used in estimating the MDLs.

Secondly, the long-term annual average TMDL (see Table 4.7.1) concentrations are estimated for both high flow and low flow strata. This is conducted for each station using a statistical methodology (the "Statistical Theory of Rollback," or "STR," described more fully in Appendix D).

Third, based on the estimated long-term average (LTA) TMDL concentrations, the MDL for each flow stratum at each station is estimated using the upper boundary percentile computed in the first step above. Finally, MDLs are computed from these MDL concentrations and their corresponding flows.

Results of the fecal bacteria MDL analysis for the Liberty Reservoir subwatersheds are shown in Table 4.7.3.

Table 4.7.3: Maximum Daily Loads Summary

Subwatershed	Flow Stratum	Maximum Daily Load (Billion *E. coli* MPN/day)	
		by Stratum	Weighted by Stratum
NPA0165	High	10,981	5,586
	Low	3,082	
BEA0016	High	756	779
	Low	789	
MDE0026	High	1,721	594
	Low	71	
MOR0040	High	4,727	2,330
	Low	1,217	
LMR0015	High	590	362
	Low	256	
Downstream Subwatershed	High	3,755	1,930
	Low	1,083	

See Appendix D for a more detailed explanation of the procedure for obtaining these daily loads.

4.8 TMDL Allocation

The Liberty Reservoir watershed fecal bacteria TMDL is composed of the following components:

$$TMDL = LA + WLA + MOS \qquad (14)$$

where,

LA = Load Allocation
WLA = Waste Load Allocation
MOS = Margin of Safety

The TMDL allocation includes load allocations (LA) for nonpoint sources and waste load allocations (WLA) for point sources including WWTPs and NPDES-regulated stormwater discharges. The Stormwater (SW) WLA includes any nonpoint source loads deemed to be transported and discharged by regulated stormwater systems. An explanation of the distribution of nonpoint source loads and point source loads to the LA and to the SW-WLA and WWTP-WLA is provided in the subsections that follow.

The margin of safety (MOS) is explicit and is incorporated in the analysis using a conservative assumption; it is not specified as a separate term. The assumption is that a 5% reduction of the criterion concentration established by MD to meet the applicable water quality standard will result in more conservative allowable loads of fecal bacteria, and thus provide the MOS. The final loads are based on average hydrological conditions, with reductions estimated based on critical hydrological conditions. The load reduction scenario results in load allocations that will achieve water quality standards. The State reserves the right to revise these allocations provided such revisions are consistent with the achievement of water quality standards.

Bacteria Source Categories and Allocation Distributions

The bacteria sources are grouped into four categories that are also consistent with divisions for various management strategies. The categories are human, domestic animal, livestock and wildlife. TMDL allocation rules are presented in Table 4.8.1. This table identifies how the TMDL will be allocated among the LA (those nonpoint sources or portions thereof not transported and discharged by stormwater systems) and the WLA (point sources including WWTPs and NPDES regulated stormwater discharges). Only the final LA or WLA is reported in this TMDL.

Table 4.8.1: Potential Source Contributions for TMDL Allocation Categories

Source Category	TMDL Allocation Categories		
	LA	WLA	
		WWTP*	Stormwater
Human	X	X	X
Domestic	X		X
Livestock	X		
Wildlife	X		X

* Industrial facilities

LA

All four bacteria source categories could potentially contribute to nonpoint source loads. For human sources, if the watershed has no MS4s or other NPDES-regulated Phase I or Phase II stormwater discharges, the nonpoint source contribution is estimated by subtracting any WWTP and/or CSO loads from the TMDL human load, and is then assigned to the LA. However, in watersheds covered by NPDES-regulated stormwater permits, any such nonpoint sources of human bacteria (i.e., beyond the reach of the sanitary sewer systems) are assigned to the SW-WLA (see below). For this TMDL, information provided by the two Counties identifies limited areas of the watershed that are subject to stormwater management controls. Therefore, in the Liberty Reservoir TMDL, the human nonpoint source load is distributed between the SW-WLA and the LA on the basis of the delineation of these areas.

Livestock loads are all assigned to the LA. Domestic animals (pets) loads are assigned to the LA in watersheds with no MS4s or other NPDES-regulated stormwater systems. Although the entire Liberty Reservoir watershed lies within counties with Phase I NPDES MS4 permits, bacteria loads from domestic animal, human and wildlife sources are distributed between the SW-WLA, for areas delineated as subject to stormwater management, and the LA for the remaining areas not served by stormwater systems.

WLA

NPDES Regulated Stormwater

EPA's guidance document, "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs" (November 2002), advises that all individual and general NPDES Phase I and Phase II stormwater permits are point sources subject to WLA assignment in the TMDL. The document acknowledges that quantification of rainfall-driven nonpoint source loads is uncertain, stating that available data and information usually are not detailed enough to determine WLAs for NPDES-regulated stormwater discharges on an outfall-specific basis; therefore, the EPA guidance allows the stormwater WLA to be expressed as an aggregate allotment.

Information regarding the stormwater management status of the Liberty Reservoir watershed, provided to MDE by Baltimore and Carroll Counties, allowed for the determination of the SW-WLA based on the spatial delineation of the extent of organized stormwater systems within each County's jurisdiction. In this case, bacteria loads from domestic animal sources and human nonpoint sources are distributed between the SW-WLA and the LA based on a ratio of the population in the areas under stormwater management to the population in remaining areas not served by organized stormwater systems. The bacteria load from wildlife sources is distributed between the SW-WLA and the LA based on a ratio of the per capita acreage in the areas under stormwater management to the per capita acreage in remaining areas not served by organized stormwater systems. This weighting allows for a greater domestic animal and human source allocation in areas more populated by humans, and a greater wildlife source allocation to areas less populated by humans. Permitted discharges outside of Phase I and Phase II MS4 areas are factored into an "Other SW-WLA" based on the percentage of the area of non-residential urban impervious land. In watersheds with no existing NPDES-regulated stormwater permits, these loads will be included entirely in the LA. [Note: The human nonpoint source load in the SW-WLA is estimated by subtracting any loads allocated to WWTPs and CSOs, if present, from the total allowable (TMDL) human load. There are no municipal and two industrial wastewater treatment facilities with NPDES permits regulating the discharge of fecal bacteria in the Liberty Reservoir watershed. There are no NPDES CSO permits in the watershed.]

The MD portion of the Liberty Reservoir watershed lies within the jurisdictions of Baltimore County and Carroll County, which both have individual Phase I MS4 permits. The municipalities of Westminster, Hampstead and Manchester in Carroll County are also covered by a general Phase II MS4 permit. Based on EPA's guidance and information made available to MDE by the two Counties, SW-WLAs are presented as combined loads for each of the areas within the three Phase II jurisdictions in Carroll County that are subject to stormwater management, including any other separately permitted stormwater dischargers within those areas. Additionally an "Other SW-WLA" is provided for Carroll County's Phase I regulated stormwater systems in the Eldersburg urban area and any other NPDES-regulated stormwater dischargers in Carroll County's portion of the watershed (outside of the three Phase II municipalities). The remaining areas of the watershed (including the entire Baltimore County portion) are outside the reach of the Counties' organized stormwater systems and therefore not subject to WLA assignment. (See Section 2.4 Source Assessment, pp. 21-22, for the Counties' stormwater management assessments of the Liberty watershed.). The SW-WLA includes loads from sources such as leaks from broken sanitary infrastructure and failing septic systems, which may be transported through the storm drain system. These loads may be more effectively controlled through other management programs, but at this time such components cannot be determined separately. As stormwater assessment and/or other program monitoring efforts result in a more refined source assessment, MDE reserves the right to revise the current SW-WLA, provided the revisions are consistent with achieving water quality standards. Upon approval of the TMDL, "NPDES-regulated municipal stormwater and small construction storm water discharges effluent limits should be expressed as BMPs or other similar requirements, rather than as numeric effluent limits" (US EPA 2002a). The SW-WLA distribution for the Liberty Reservoir watershed is presented in Table 4.8.2.

Table 4.8.2: Annual Average Stormwater Allocations in the Liberty Reservoir Watershed

Subwatershed	Hampstead SW-WLA	Manchester SW-WLA	Westminster SW-WLA	Carroll County Other SW-WLA
	(Billion MPN *E. coli*/year)			
NPA0165	458	243	1,330	1,506
BEA0016	0	0	32	340
MDE0026	0	0	0	67
MOR0040	0	0	0	58
LMR0015	0	0	0	967
Downstream Subwatershed	0	0	0	4,325

Municipal and Industrial WWTPs

Based on MDE's point source permitting information, there are two industrial NPDES permitted point source facilities regulating the discharge of fecal bacteria in the Liberty Reservoir basin, which include: 1) Congoleum Corporation (MD0001384), and 2) AG/GFI Hampstead, Inc. (MD0001881). The fecal bacteria WLAs for the WWTPs are typically estimated using the design flows of the plants stated in the facilities' NPDES permits and the *E. coli* criterion of 126 MPN/100ml. Since the permits for these two minor industrial facilities provide no design flows, the maximum flows reported in 2004 were used to calculate the WLA. Bacteria loads assigned to the WWTPs are allocated as the WWTP-WLA.

4.9 Summary

The long-term annual average TMDL and TMDL allocations are presented in Table 4.9.1. Table 4.9.2 presents the maximum daily loads for the subwatersheds.

Table 4.9.1: Annual Average TMDL

Subwatershed	Total Allocation	LA	SW-WLA	WWTP-WLA
	(Billion MPN *E. coli* /year)			
NPA0165	146,397	141,816	3,536	1,045
BEA0016	20,425	20,054	372	0
MDE0026	20,333	20,265	67	0
MOR0040	54,496	54,438	58	0
LMR0015	9,044	8,077	967	0
Downstream Subwatershed	110,313	105,988	4,325	0
***TMDL*[1]**	**361,008**	**350,638**	**9,325**	**1,045**

[1]The MOS is incorporated.

Table 4.9.2: Maximum Daily Loads

Subwatershed	Total Allocation	LA	SW-WLA	WWTP-WLA
	(Billion MPN *E. coli* /year)			
NPA0165	5,586	5,434	143	9
BEA0016	779	764	14	0
MDE0026	594	592	2	0
MOR0040	2,330	2,328	2	0
LMR0015	362	323	39	0
Downstream Subwatershed	1,930	1,854	76	0
***MDL*[1]**	**11,580**	**11,295**	**276**	**9**

[1]The MOS is incorporated.

The long-term annual average fecal bacteria TMDL summary for the entire Liberty Reservoir basin is presented in Table 4.9.3.

Table 4.9.3: Annual Average TMDL Summary

MD 8-Digit Liberty Reservoir Fecal Bacteria TMDL (Billion MPN *E. coli*/year)								
				WLA				
TMDL	=	**LA**	+	**SW WLA**	+	**WWTP WLA**	+	**MOS**
361,008	=	350,638	+	9,325	+	1,045	+	Incorpo-rated

The fecal bacteria MDL summary for the entire Liberty Reservoir basin is presented in Table 4.9.4.

Table 4.9.4: MDL Summary

MD 8-Digit Liberty Reservoir Fecal Bacteria MDL Summary (Billion MPN *E. coli*/day)								
				WLA				
MDL	=	**LA**	+	**SW WLA**	+	**WWTP WLA**	+	**MOS**
11,580	=	11,295	+	276	+	9	+	Incorpo-rated

In certain watersheds, the goal of meeting water quality standards may require very high reductions that are not achievable with current technologies and management practices. In this situation, where there is no feasible TMDL scenario, MPRs are increased to provide estimates of the reductions required to meet water quality standards. In the subwatersheds of the Liberty Reservoir basin, water quality standards can be achieved in three out of the six subwatersheds with the maximum practicable reduction rates specified in Table 4.6.3. However, in three subwatersheds water quality standards can not be achieved with the maximum practicable reduction rates specified in Table 4.6.3. The TMDLs shown in Tables 4.9.1 and 4.9.2 represent reductions from current bacteria loadings that are beyond practical reductions for subwatershed NPA0165, MDE0026, and the downstream subwatershed. In cases where such high reductions are required to meet standards, it is expected that the first stage of implementation will be to carry out the MPR scenario.

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the Clean Water Act and current EPA regulations require reasonable assurance that the TMDL load and waste load allocations can and will be implemented. In the Liberty Reservoir watershed, the TMDL analysis indicates that, for three of the subwatersheds (NPA0165, MDE0026, and the downstream subwatershed) the reduction of fecal bacteria is beyond the MPR targets. These MPR targets were defined based on a literature review of BMPs effectiveness and assuming a zero reduction for wildlife sources. The Liberty Reservoir, North Branch Patapsco River, Middle Run, and the downstream subwatershed and their tributaries may not be able to attain water quality standards. The fecal bacteria load reductions required to meet water quality criteria in the Liberty Reservoir basin are not feasible by implementing effluent limitations and cost-effective, reasonable BMPs to nonpoint sources. Therefore, MDE proposes a staged approach to implementation beginning with the MPR scenario, with regularly scheduled follow-up monitoring to assess the effectiveness of the implementation plan.

Additional reductions will be achieved through the implementation of BMPs; however, the literature reports considerable uncertainty concerning the effectiveness of BMPs in treating bacteria. As an example, pet waste education programs have varying results based on stakeholder involvement. Additionally, the extent of wildlife reduction associated with various BMPs methods (e.g., structural, non-structural, etc.) is uncertain. Therefore, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality and human health risk, with consideration given to ease of implementation and cost. The iterative implementation of BMPs in the watershed has several benefits: tracking of water quality improvements following BMP implementation through follow-up stream monitoring; providing a mechanism for developing public support through periodic updates on BMP implementation; and helping to ensure that the most cost-effective practices are implemented first.

Potential funding sources for implementation include the Maryland's Agricultural Cost Share Program (MACS), which provides grants to farmers to help protect natural resources, and the Environmental Quality and Incentives Program, which focuses on implementing conservation practices and BMPs on land involved with livestock and production. Though not directly linked, it is assumed that the nutrient management plans from the Water Quality Improvement Act of 1998 (WQIA) will have some reduction of bacteria from manure application practices.

Implementation and Wildlife Sources

It is expected that, in some waters for which TMDLs will be developed, the bacteria source analysis indicates that after controls are in place for all anthropogenic sources, the waterbody will not meet water quality standards. However, while neither Maryland nor EPA is proposing the elimination of wildlife to allow for the attainment of water quality standards, managing the overpopulation of wildlife remains an option for state and local stakeholders.

After developing and implementing, to the maximum extent possible, a reduction goal based on the anthropogenic sources identified in the TMDL, Maryland anticipates that implementation to reduce the controllable nonpoint sources may also reduce some wildlife inputs to the waters.

6.0 PUBLIC PARTICIPATION

Stakeholders were informed by a March 28, 2008 MDE mailing of a notice of intent to develop a fecal bacteria TMDL for the Liberty Reservoir basin. The notice letters provided MDE contact information and offered upon request an informational briefing on the proposed TMDL. MDE received requests for a briefing from Carroll County's Health Department and Department of Planning, as well as from Mr. Gould Charshee of the Baltimore Metropolitan Council's Reservoir Technical Group (RTG). An informational briefing was provided to the RTG on July 10, 2008 and notification letters announcing availability of the draft TMDL for public review provided information on the briefing, noting that it was open to all interested parties. Another briefing was provided to officials of the Carroll County government on July 17, 2008.

A public notice of intent to establish the Liberty Reservoir fecal bacteria TMDL, announcing the opening and closing dates of the formal 30-day Public Comment Period, was published in The Carroll County Times and the Baltimore County newspaper, The Jeffersonian. The notice was also sent to MDE's stakeholder distribution list for the Liberty Reservoir watershed and all other interested parties. All were invited to send written comments on the draft TMDL to MDE. The public notice announced the availability of the draft TMDL documents, which were placed in identified public libraries located in each of the two counties that share the watershed. The 30-day public notice also provided information on how to access the draft TMDL documents on MDE's website.

All written comments received by the close of the comment period are recorded and formally responded to in a Comment Response Document (CRD), to be included in the draft final TMDL documentation package submitted to EPA for the Agency's approval. Receipt of each set of comments is acknowledged by MDE, either by letter or email to comment authors. Following EPA approval of the TMDL, the responses are made available when the CRD is posted on MDE's website, together with the final approved TMDL documentation. The CRD is also mailed to stakeholders, including all those who sent comments to MDE, along with an approval notification letter.

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APPENDIX A – BACTERIA DATA

Table A-1: Measured Bacteria Concentration and Daily Flow Frequency

Station	Date	Daily flow frequency	*E. Coli* MPN/100ml
BEA0016	11/05/2003	18.7500	200
BEA0016	11/19/2003	2.6848	280
BEA0016	12/03/2003	20.6120	150
BEA0016	12/17/2003	1.4290	930
BEA0016	01/05/2004	9.4255	40
BEA0016	01/20/2004	20.6120	50
BEA0016	02/02/2004	10.7679	30
BEA0016	02/17/2004	20.6120	70
BEA0016	03/01/2004	24.7113	20
BEA0016	03/15/2004	22.6905	20
BEA0016	04/05/2004	12.4134	70
BEA0016	04/19/2004	15.5889	30
BEA0016	05/10/2004	32.3037	170
BEA0016	05/24/2004	34.7575	160
BEA0016	06/07/2004	29.8788	280
BEA0016	06/21/2004	44.3418	260
BEA0016	07/06/2004	48.2679	4400
BEA0016	07/19/2004	52.3961	570
BEA0016	08/09/2004	60.1617	200
BEA0016	08/23/2004	71.0162	60
BEA0016	09/07/2004	77.0208	150
BEA0016	09/20/2004	74.2783	310
BEA0016	10/04/2004	57.4913	130
BEA0016	10/18/2004	60.6813	20

Station	Date	Daily flow frequency	*E. Coli* MPN/100ml
LMR0015	11/05/2003	14.0837	120
LMR0015	11/19/2003	1.3232	20
LMR0015	12/03/2003	13.1103	70
LMR0015	12/17/2003	0.7605	1330
LMR0015	01/05/2004	11.7262	30
LMR0015	01/20/2004	31.5589	10
LMR0015	02/02/2004	36.7452	10
LMR0015	02/17/2004	23.4677	60
LMR0015	03/01/2004	27.9544	20
LMR0015	03/15/2004	29.1863	10
LMR0015	04/05/2004	12.0760	10
LMR0015	04/19/2004	16.1977	50
LMR0015	05/10/2004	35.6350	110
LMR0015	05/24/2004	51.7567	50
LMR0015	06/07/2004	42.7072	170
LMR0015	06/21/2004	56.5323	360
LMR0015	07/06/2004	58.8897	260
LMR0015	07/19/2004	64.2129	250
LMR0015	08/09/2004	61.4144	190
LMR0015	08/23/2004	73.7643	510
LMR0015	09/07/2004	85.7186	100
LMR0015	09/20/2004	70.1445	490
LMR0015	10/04/2004	58.8897	620
LMR0015	10/18/2004	70.1445	60

Station	Date	Daily flow frequency	*E. Coli* MPN/100ml
MDE0026	11/05/2003	18.7500	550
MDE0026	11/19/2003	2.6848	370
MDE0026	12/03/2003	20.6120	70
MDE0026	12/17/2003	1.4290	24190
MDE0026	01/05/2004	9.4255	110
MDE0026	01/20/2004	20.6120	70
MDE0026	02/02/2004	10.7679	30
MDE0026	02/17/2004	20.6120	100
MDE0026	03/01/2004	24.7113	120
MDE0026	03/15/2004	22.6905	60
MDE0026	04/05/2004	12.4134	250
MDE0026	04/19/2004	15.5889	190
MDE0026	05/10/2004	32.3037	310
MDE0026	05/24/2004	34.7575	590
MDE0026	06/07/2004	29.8788	860
MDE0026	06/21/2004	44.3418	420
MDE0026	07/06/2004	48.2679	840
MDE0026	07/19/2004	52.3961	1670
MDE0026	08/09/2004	60.1617	670
MDE0026	08/23/2004	71.0162	250
MDE0026	09/07/2004	77.0208	280
MDE0026	09/20/2004	74.2783	1550
MDE0026	10/04/2004	57.4913	590
MDE0026	10/18/2004	60.6813	220

Station	Date	Daily flow frequency	*E. Coli* MPN/100ml
MOR0040	11/05/2003	14.0837	130
MOR0040	11/19/2003	1.3232	90
MOR0040	12/03/2003	13.1103	60
MOR0040	12/17/2003	0.7605	1990
MOR0040	01/05/2004	11.7262	70
MOR0040	01/20/2004	31.5589	10
MOR0040	02/02/2004	36.7452	10
MOR0040	02/17/2004	23.4677	110
MOR0040	03/01/2004	27.9544	20
MOR0040	03/15/2004	29.1863	10
MOR0040	04/05/2004	12.0760	90
MOR0040	04/19/2004	16.1977	50
MOR0040	05/10/2004	35.6350	50
MOR0040	05/24/2004	51.7567	60
MOR0040	06/07/2004	42.7072	320
MOR0040	06/21/2004	56.5323	130
MOR0040	07/06/2004	58.8897	960
MOR0040	07/19/2004	64.2129	380
MOR0040	08/09/2004	61.4144	90
MOR0040	08/23/2004	73.7643	80
MOR0040	09/07/2004	85.7186	120
MOR0040	09/20/2004	70.1445	580
MOR0040	10/04/2004	58.8897	280
MOR0040	10/18/2004	70.1445	60

Station	Date	Daily flow frequency	*E. Coli* MPN/100ml
NPA0165	11/05/2003	18.8905	160
NPA0165	11/19/2003	2.3199	90
NPA0165	12/03/2003	20.2161	120
NPA0165	12/17/2003	1.3112	9800
NPA0165	01/05/2004	9.0778	60
NPA0165	01/20/2004	21.2248	50
NPA0165	02/02/2004	28.6311	10
NPA0165	02/17/2004	20.6628	40
NPA0165	03/01/2004	24.8991	30
NPA0165	03/15/2004	22.9827	20
NPA0165	04/05/2004	6.6427	190
NPA0165	04/19/2004	15.7637	90
NPA0165	05/10/2004	29.3228	150
NPA0165	05/24/2004	34.7262	320
NPA0165	06/07/2004	19.7406	880
NPA0165	06/21/2004	48.5879	320
NPA0165	07/06/2004	49.5677	5800
NPA0165	07/19/2004	51.7147	390
NPA0165	08/09/2004	48.5879	230
NPA0165	08/23/2004	61.5850	110
NPA0165	09/07/2004	73.5879	160
NPA0165	09/20/2004	56.4841	1620
NPA0165	10/04/2004	58.9914	190
NPA0165	10/18/2004	67.6081	70

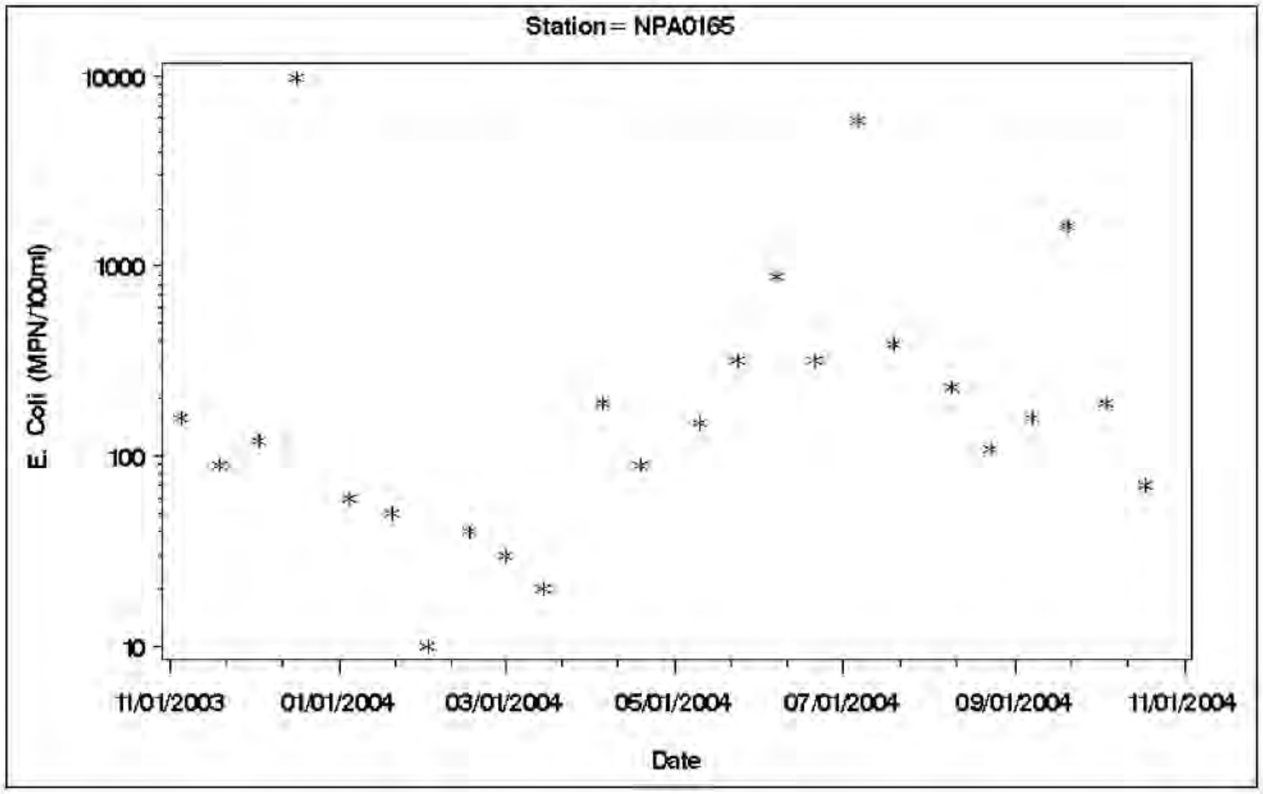

Figure A-1: ***E. coli*** **Concentration vs. Time for MDE Monitoring Station NPA0165**

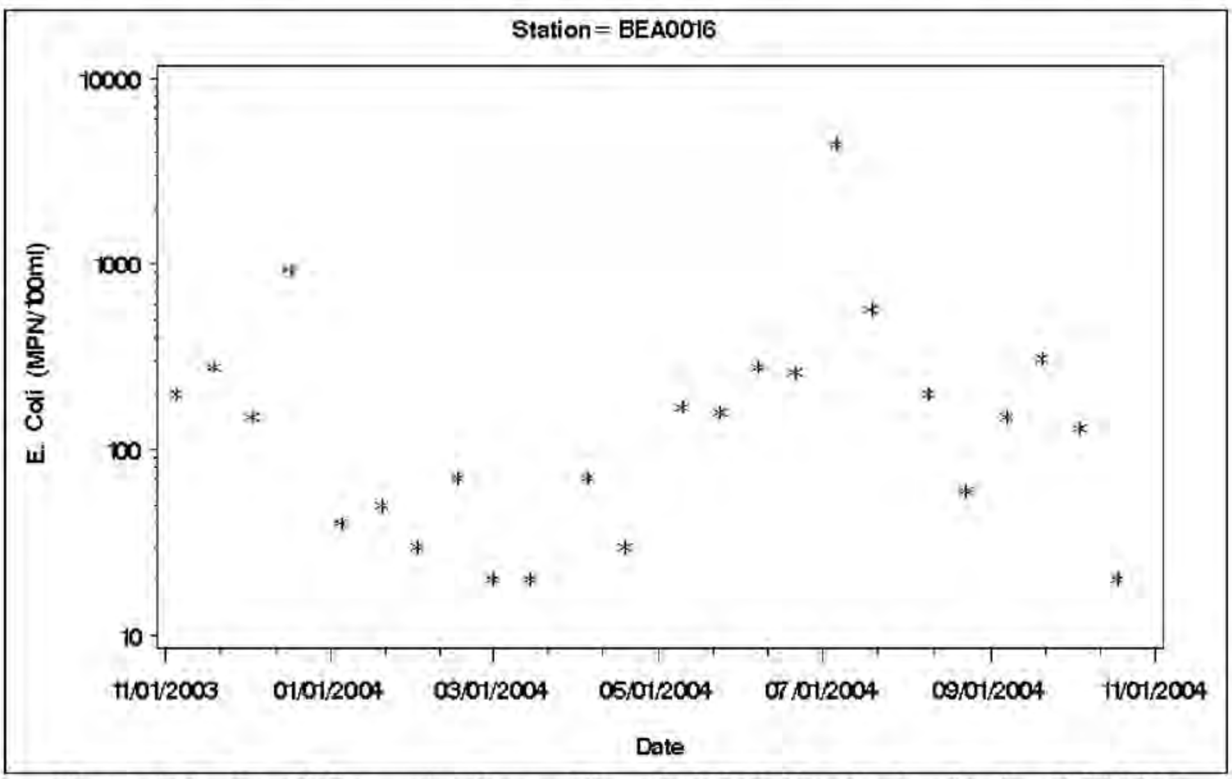

Figure A-2: ***E. coli*** **Concentration vs. Time for MDE Monitoring Station BEA0016**

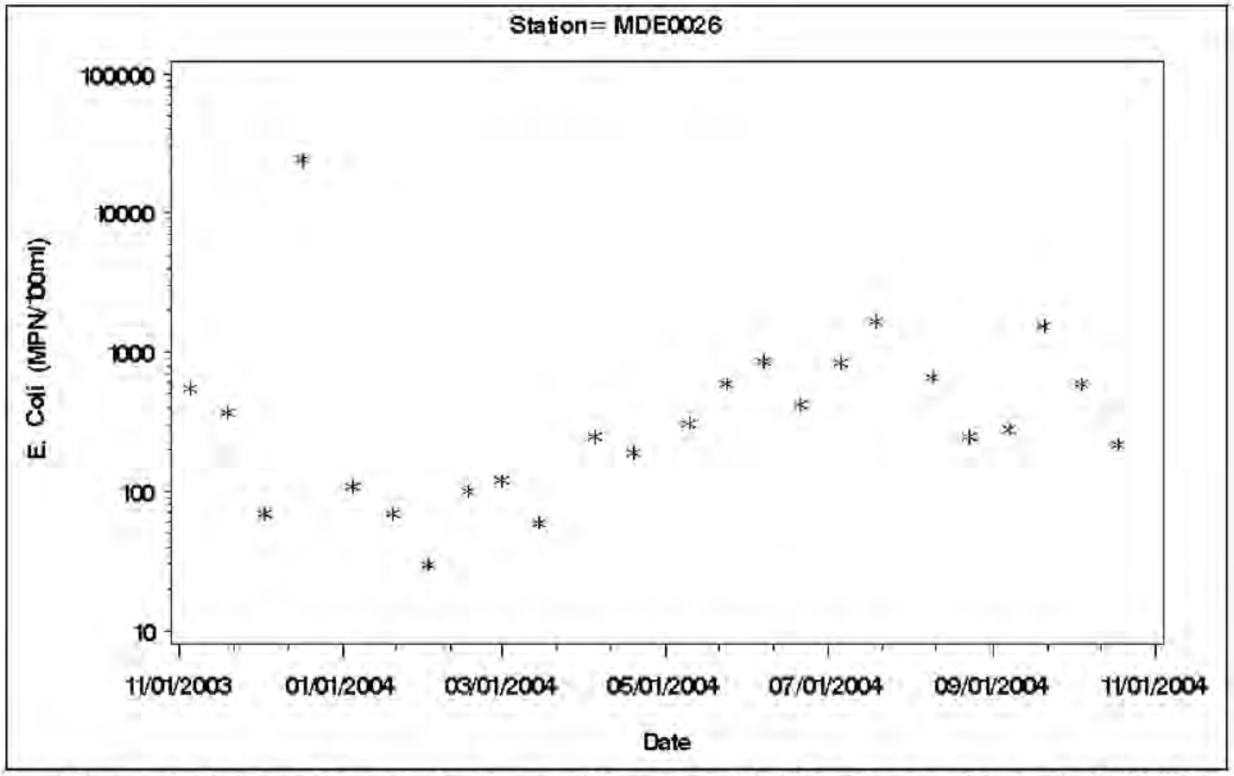

Figure A-3: *E. coli* Concentration vs. Time for MDE Monitoring Station MDE0026

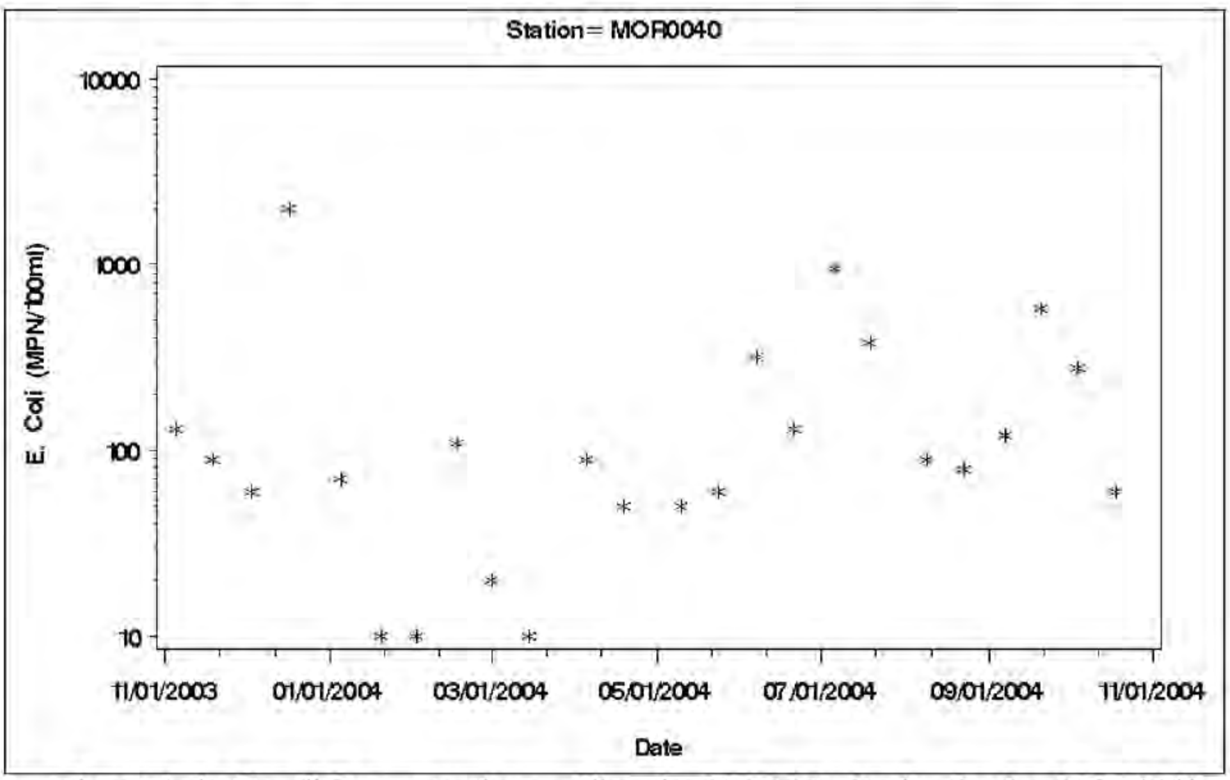

Figure A-4: *E. coli* Concentration vs. Time for MDE Monitoring Station MOR0040

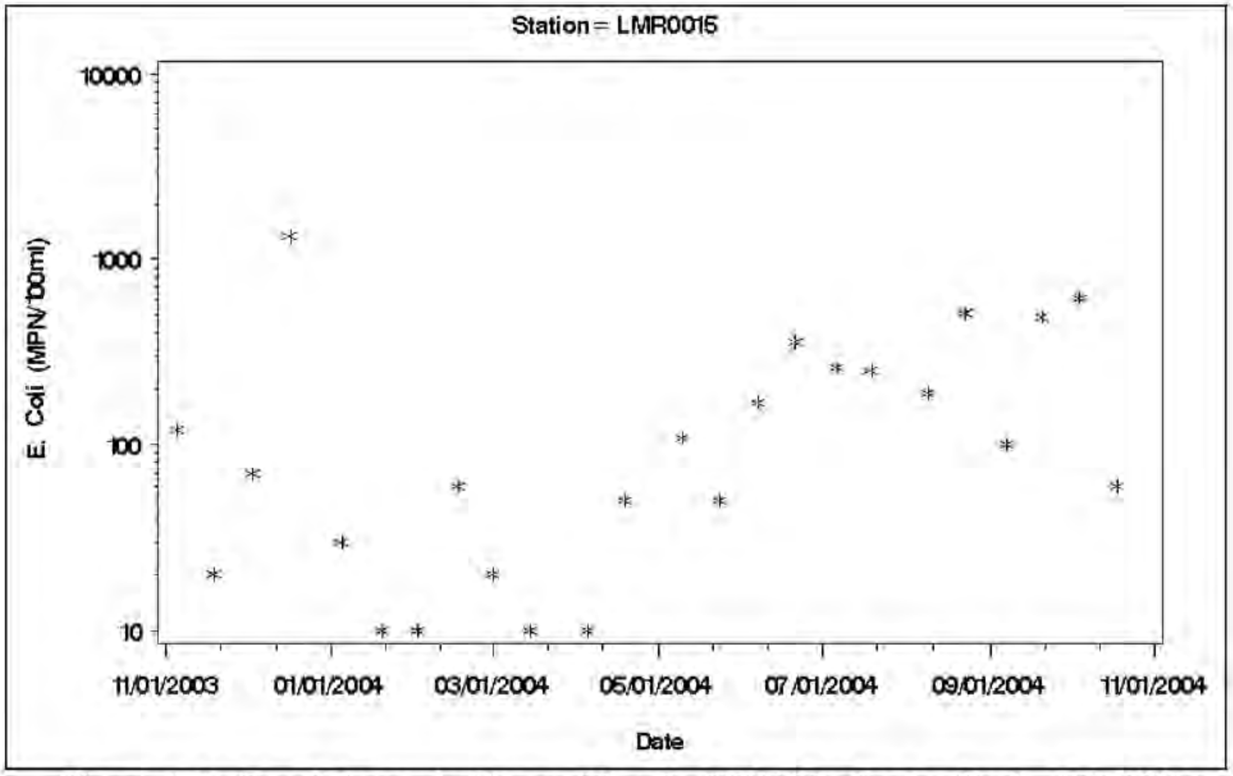

Figure A-5: *E. coli* Concentration vs. Time for MDE Monitoring Station LMR0015

APPENDIX B – FLOW DURATION CURVE ANALYSIS TO DEFINE STRATA

The Liberty Reservoir basin was assessed to determine hydrologically significant strata. The purpose of these strata is to apply weights to monitoring data and thus (1) reduce bias associated with the monitoring design and (2) approximate a critical condition for TMDL development. The strata group hydrologically similar water quality samples and provide a better estimate of the mean concentration at the monitoring station.

The flow duration curve for a watershed is a plot of all possible daily flows, ranked from highest to lowest, versus their probability of exceedance. In general, the higher flows will tend to be dominated by excess runoff from rain events and the lower flows will result from drought type conditions. The mid-range flows are a combination of high base flow with limited runoff and lower base flow with excess runoff. The range of these mid-level flows will vary with soil antecedent conditions. The purpose of the following analysis is to identify hydrologically significant groups, based on the previously described flow regimes, within the flow duration curve.

Flow Analysis

Three USGS gage stations are present in the Liberty Reservoir basin. The gage stations, #01586000 near Emory and Glen Falls Road, #01586210 near Gamber and Hughs road, and #01586610 near Poole road and Morgan Run were used for this analysis. The dates of information used were from October 1, 1988 to September 30, 2007 for gage stations 01586000 and 01586210 and from October 1, 1988 to September 30, 2006 for gage station 01586610. A flow duration curve for this gage station is presented in Figure B-1.

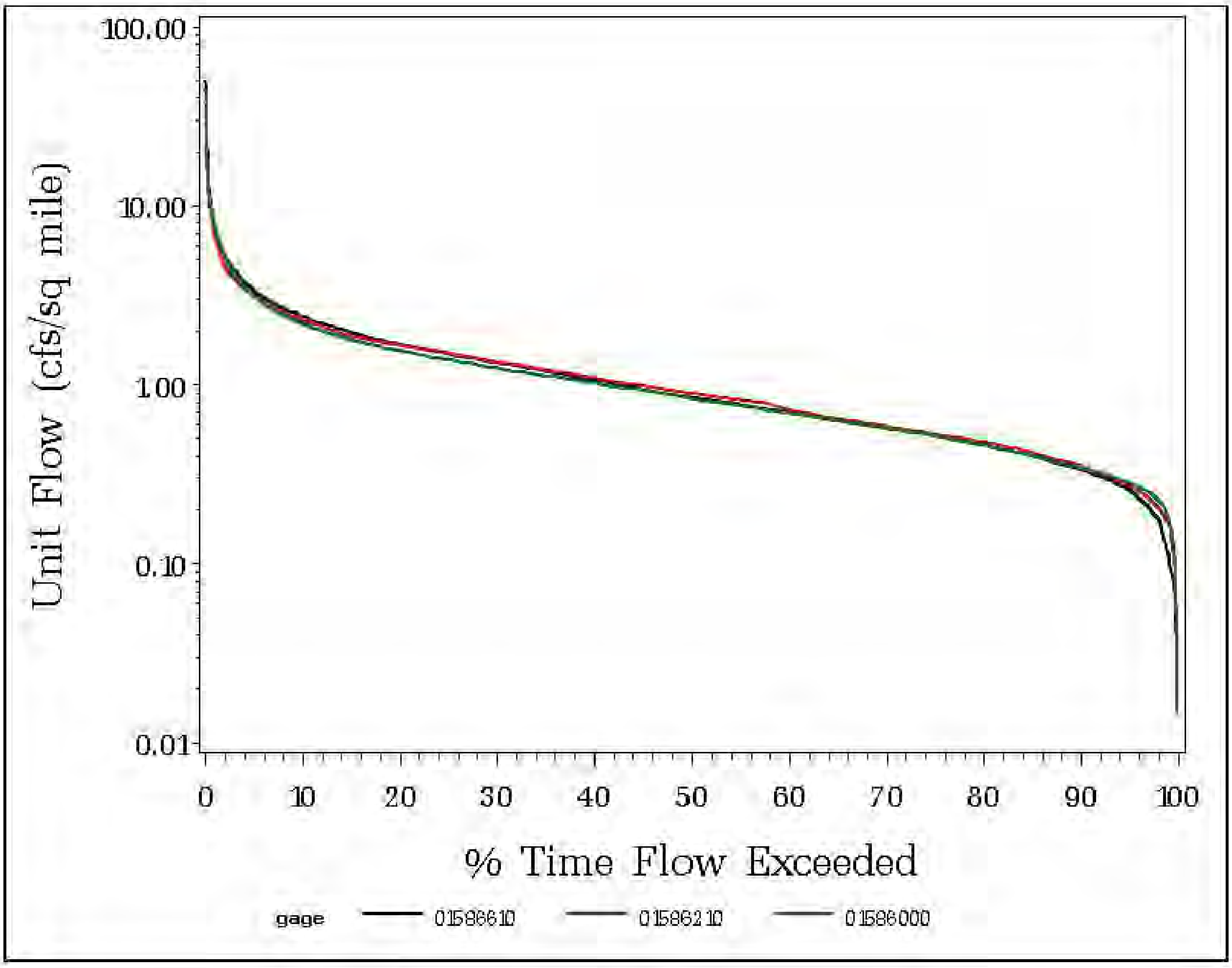

Figure B-1: Flow Duration Curve for USGS Gages 01586610, 01586210, and 01586000

Based on the flow data from the North Branch Patapsco River gage station, the long-term average daily unit flow is 1.21 cfs/sq. mile, for the Beaver Run gage station the long-term average daily unit flow is 1.23 cfs/sq. mile and for the Morgan Run gage station, the long-term average daily unit flow is 1.27 cfs/sq. mile, which corresponds to a flow frequency of 32%. Using the definition of a high flow condition as occurring when flows are higher than the long-term average flow and a low flow condition as occurring when flows are lower than the long-term average flow, the 32 percentile threshold was selected to define the limits between high flows and low flows in this watershed. Therefore, a high flow condition will be defined as occurring when the daily flow duration percentile is less than 32% and a low flow condition will be defined as occurring when the daily flow duration percentile is greater than 32%. Definitions of high and low range flows are presented in Table B-1.

Table B-1: Definition of Flow Regimes

High Flow	Represents conditions where stream flow tends to be dominated by surface runoff.
Low Flow	Represents conditions where stream flow tends to be more dominated by groundwater flow.

Flow Data Analysis

The final analysis to define the daily flow duration intervals (flow regions, strata) includes the bacteria monitoring data. Bacteria (*E. coli*) monitoring data are "placed" within the regions (strata) based on the daily flow duration percentile of the date of sampling. Figures B-2 to B-11 show the Liberty Reservoir basin *E. coli* monitoring data with corresponding flow frequency for the average annual and the seasonal conditions.

Maryland's water quality standards for bacteria state that, when available, the geometric mean indicator should be based on at least five samples taken representatively over 30 days. Therefore, in situations in which fewer than five samples "fall" within a particular flow regime interval, the interval and the adjacent interval will be joined. In the Liberty Reservoir basin, for the annual average flow condition, there are sufficient samples in both the high flow and low flow strata to estimate the geometric means. However, in the seasonal (May 1st – September 30th) flow condition, there are no samples within the high flow strata; therefore, for this condition an average seasonal geometric mean will be calculated.

Weighting factors for estimating a weighted geometric mean are based on the frequency of each flow stratum during the averaging period. The weighting factors for the averaging periods and hydrological conditions are presented in Table B-2. Averaging periods are defined in this report as:

(1) Average Annual Hydrological Condition
(2) Annual High Flow Condition
(3) Annual Low Flow Condition
(4) Seasonal (May 1st – September 30th) Average Flow Condition

Weighted geometric means for the average annual and the seasonal conditions are plotted with the monitoring data on Figures B-2 to B-11.

Table B-2: Weighting Factors for Estimation of Geometric Mean

USGS Gage	Hydrological Condition		Averaging Period	Water Quality Data Used	Fraction High Flow	Fraction Low Flow	Condition Period
01586000	Annual	Average	365 days	All	0.32	0.68	Long Term Average
		Wet	365 days	All	0.778	0.223	May 2003 – May 2004
		Dry	365 days	All	0.019	0.981	Sept. 2001 – Sept. 2002
	Seasonal	Average	May 1st – Sept. 30th	May 1st – Sept. 30th	N/A	N/A	Long-Term Average For May – Sept. Period
01586210	Annual	Average	365 days	All	0.32	0.68	Long Term Average
		Wet	365 days	All	0.805	0.196	Jan. 1997 – Jan. 1998
		Dry	365 days	All	0.017	0.984	Sept. 2001 – Sept. 2002
	Seasonal	Average	May 1st – Sept. 30th	May 1st – Sept. 30th	N/A	N/A	Long-Term Average For May – Sept. Period
01586610	Annual	Average	365 days	All	0.32	0.68	Long Term Average
		Wet	365 days	All	0.934	0.066	Jan. 1996 – Jan. 1997
		Dry	365 days	All	0.011	0.989	Sept. 2001 – Sept. 2002
	Seasonal	Average	May 1st – Sept. 30th	May 1st – Sept. 30th	N/A	N/A	Long-Term Average For May – Sept. Period

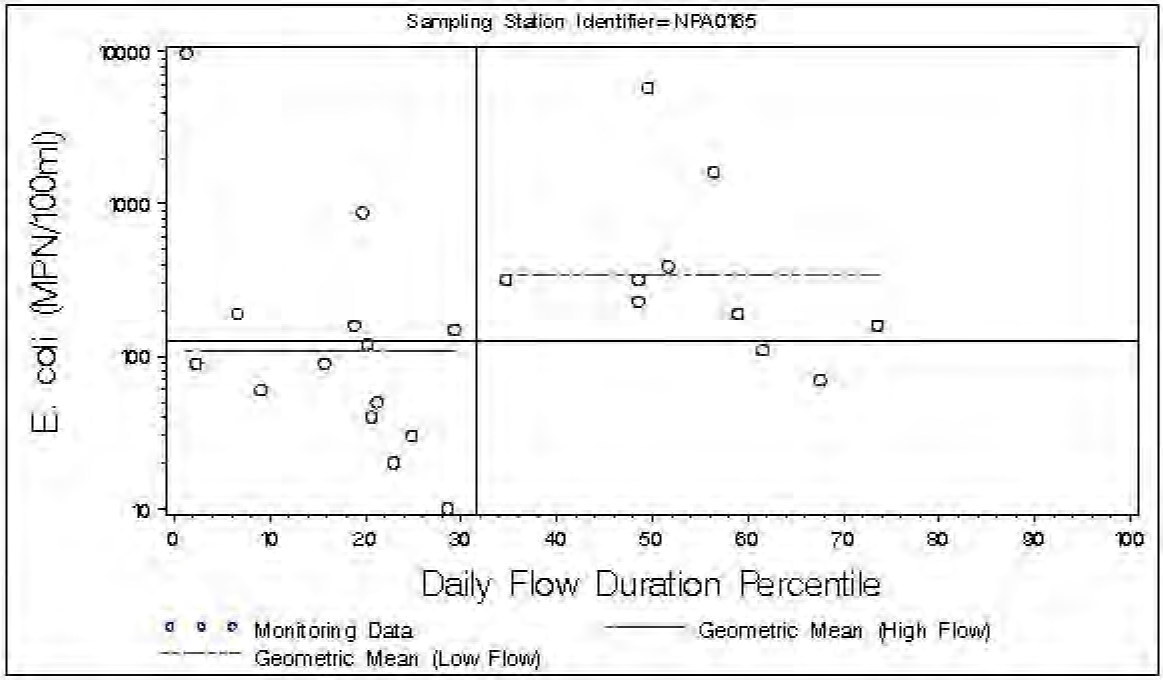

Figure B-2: *E. coli* Concentration vs. Flow Duration for Monitoring Station NPA0165 (Annual Condition)

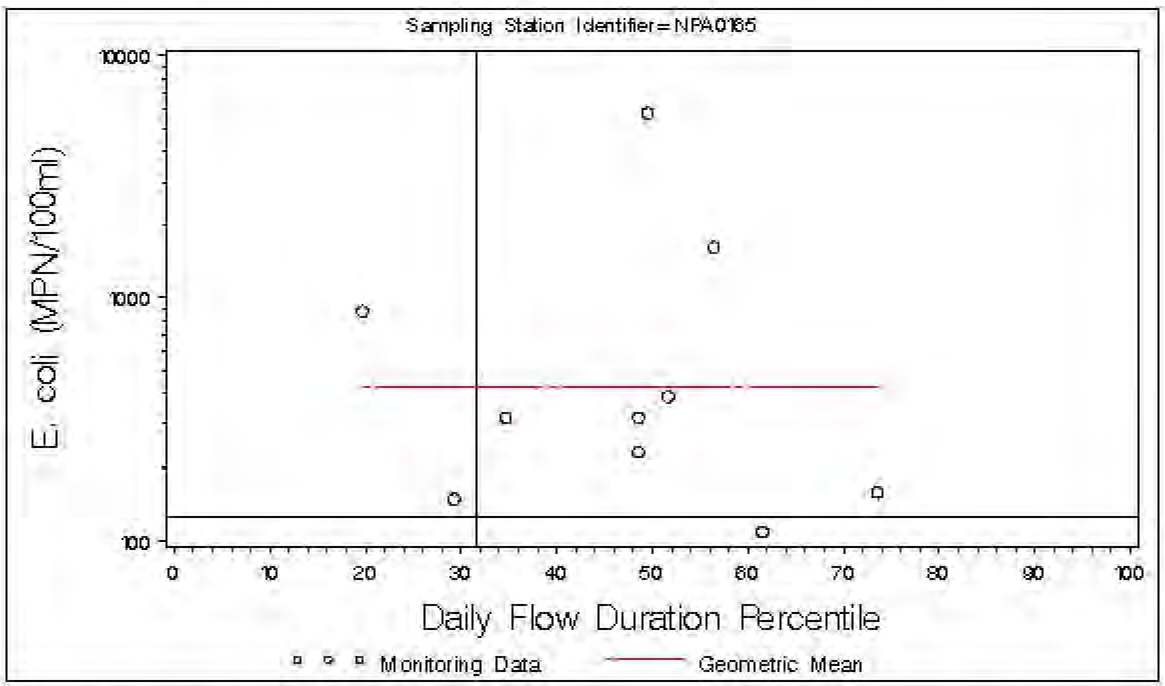

Figure B-3: *E. coli* Concentration vs. Flow Duration for Monitoring Station NPA0165 (Seasonal Condition)

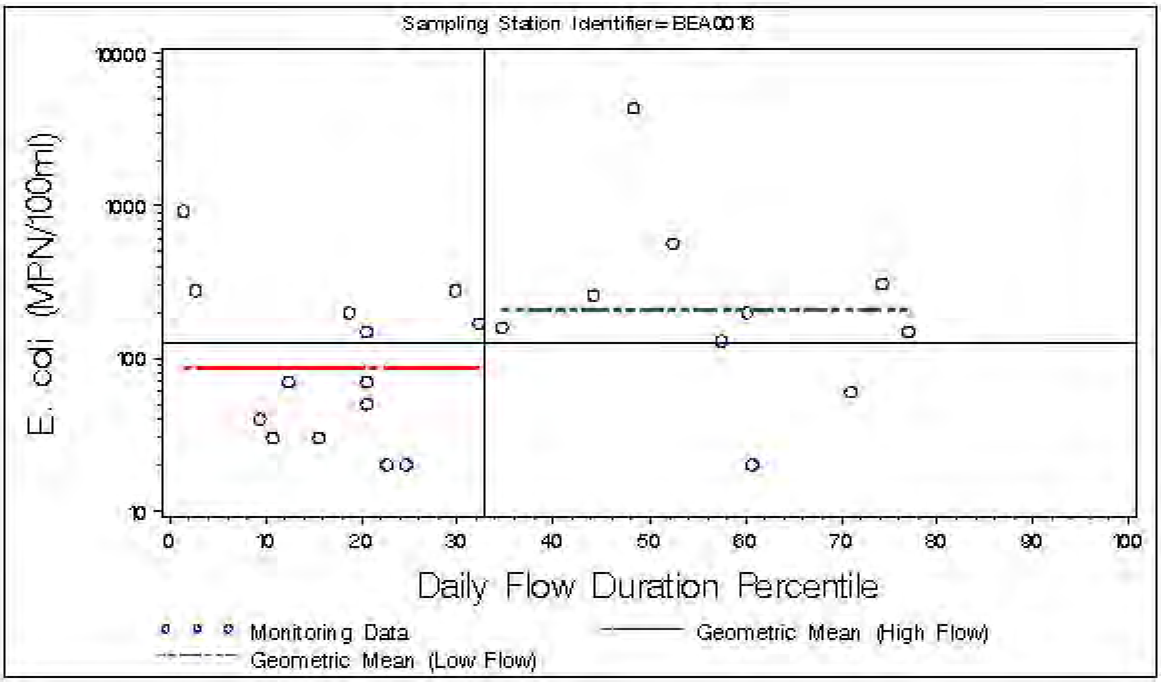

Figure B-4: *E. coli* Concentration vs. Flow Duration for Monitoring Station BEA0016 (Annual Condition)

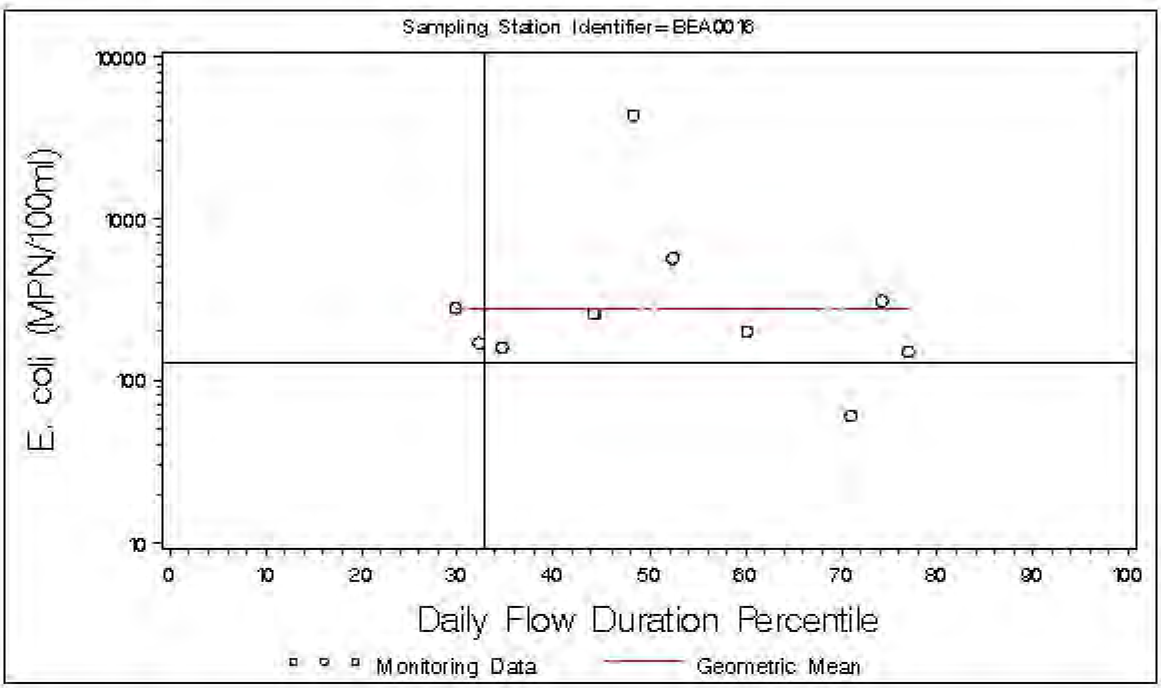

Figure B-5: *E. coli* Concentration vs. Flow Duration for Monitoring Station BEA0016 (Seasonal Condition)

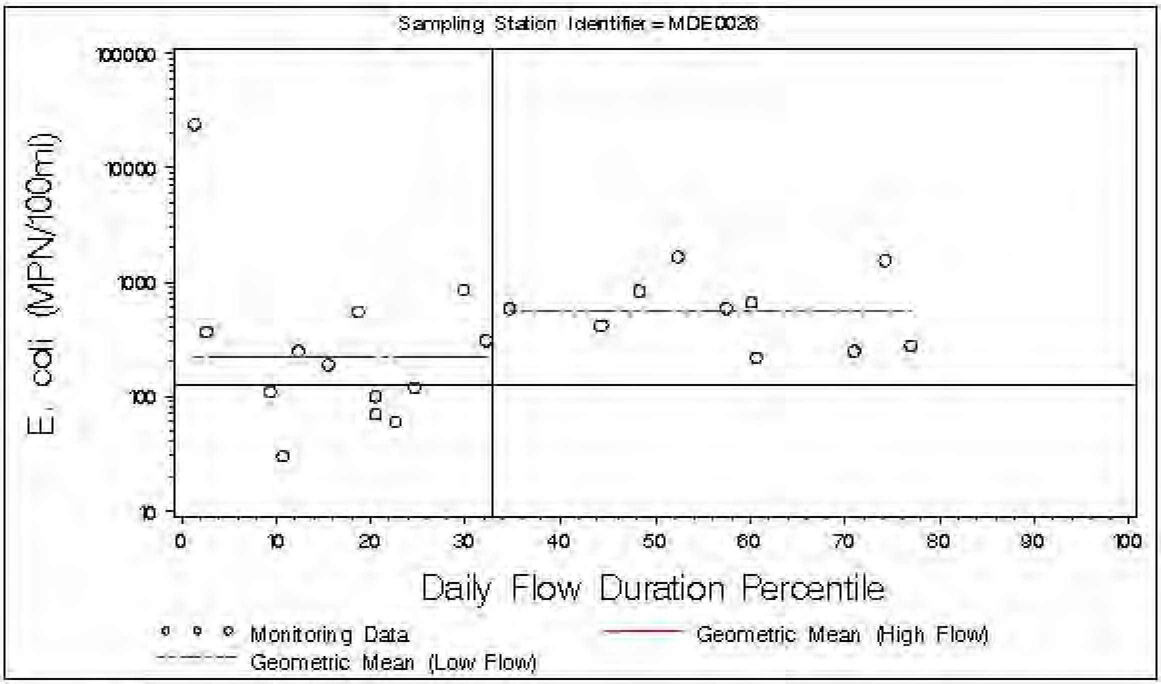

Figure B-6: *E. coli* Concentration vs. Flow Duration for Monitoring Station MDE0026 (Annual Condition)

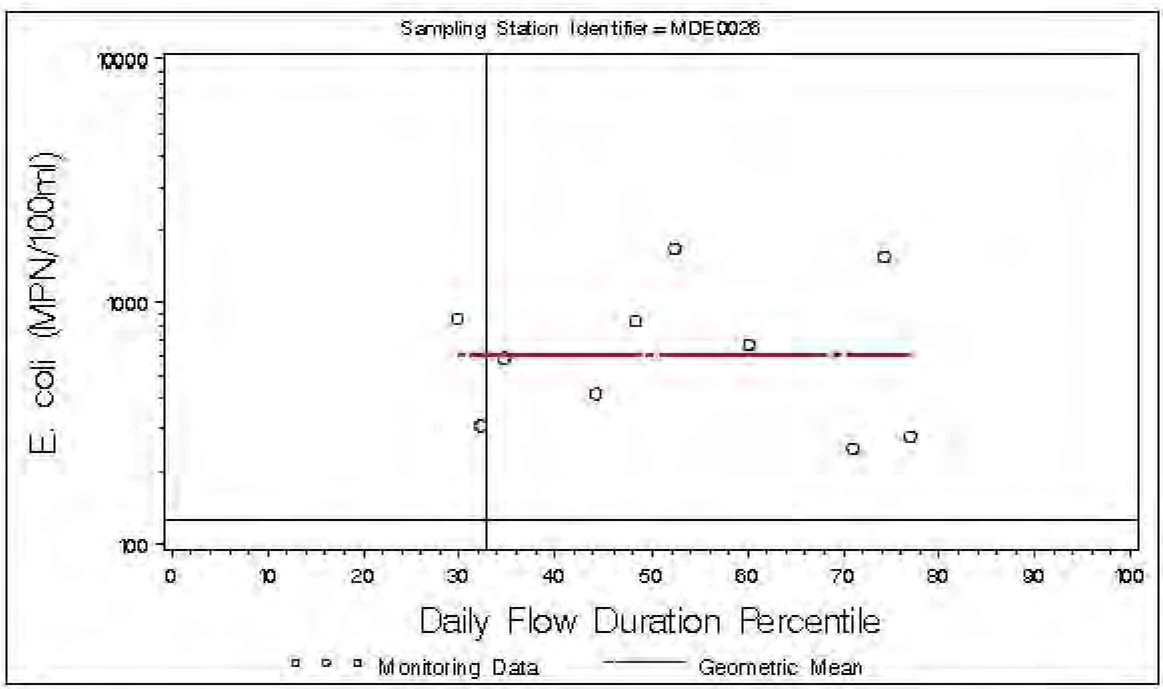

Figure B-7: *E. coli* Concentration vs. Flow Duration for Monitoring Station MDE0026 (Seasonal Condition)

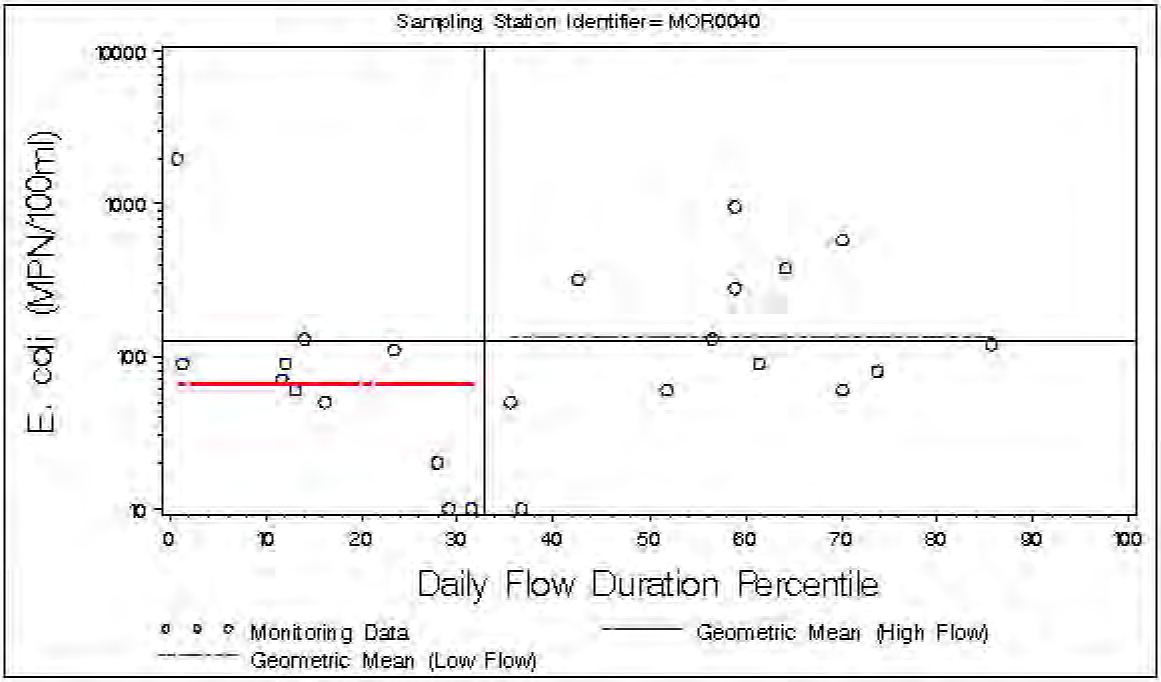

Figure B-8: *E. coli* Concentration vs. Flow Duration for Monitoring Station MOR0040 (Annual Condition)

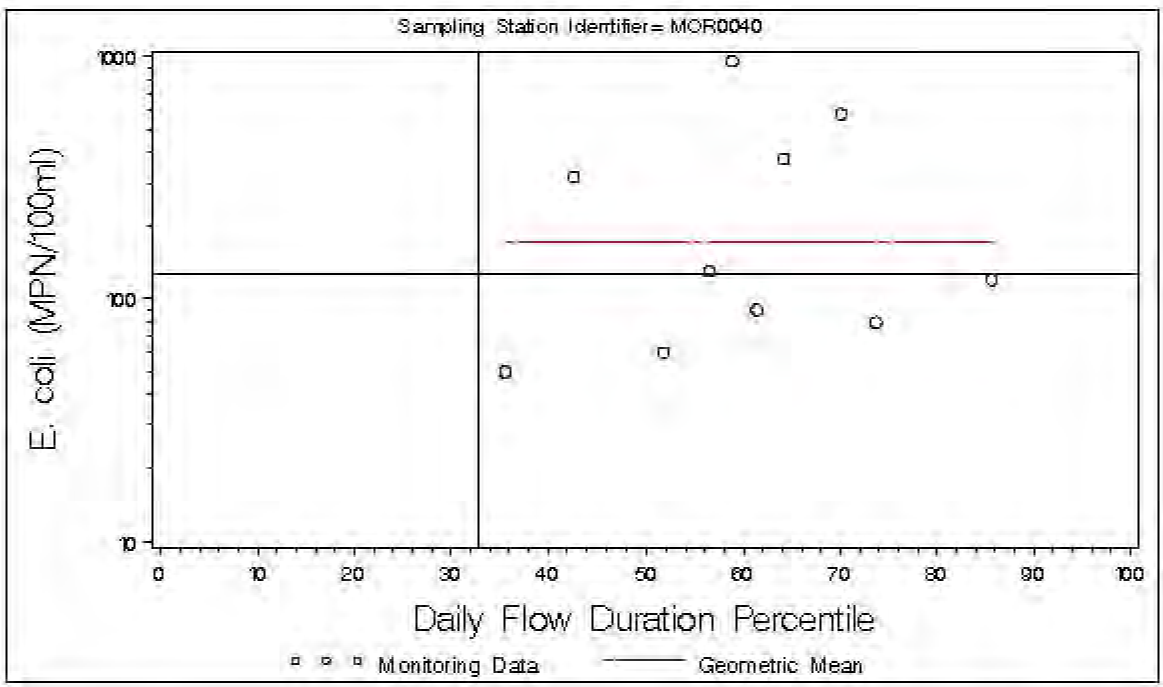

Figure B-9: *E. coli* Concentration vs. Flow Duration for Monitoring Station MOR0040 (Seasonal Condition)

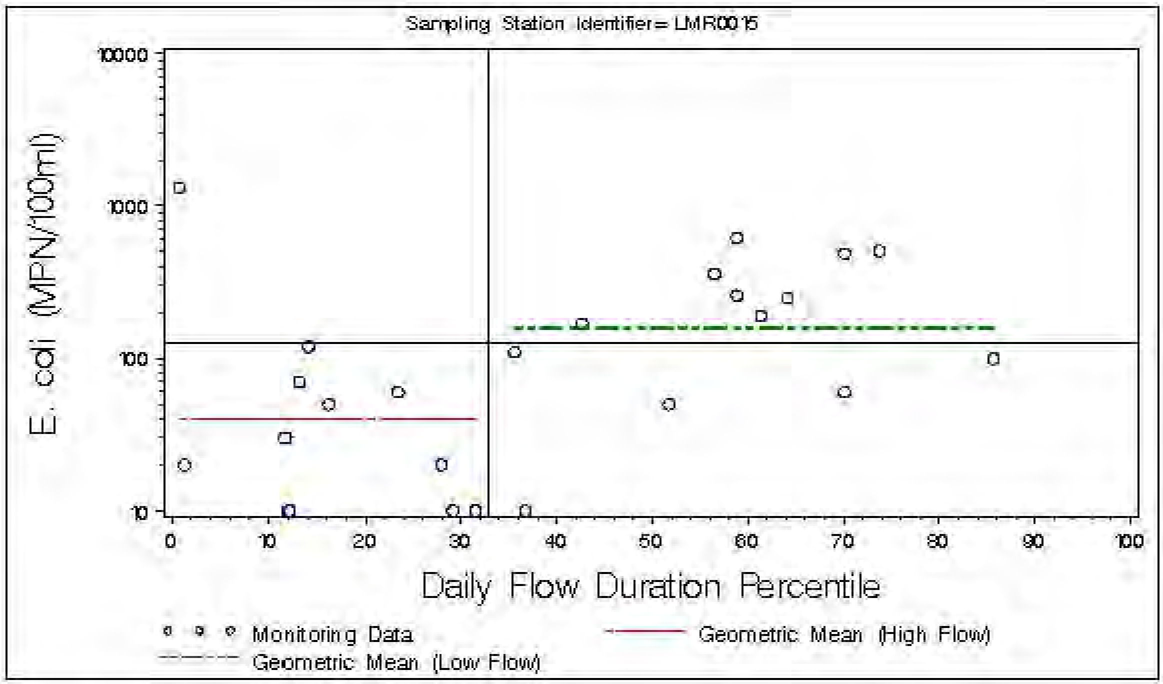

Figure B-10: *E. coli* Concentration vs. Flow Duration for Monitoring Station LMR0015 (Annual Condition)

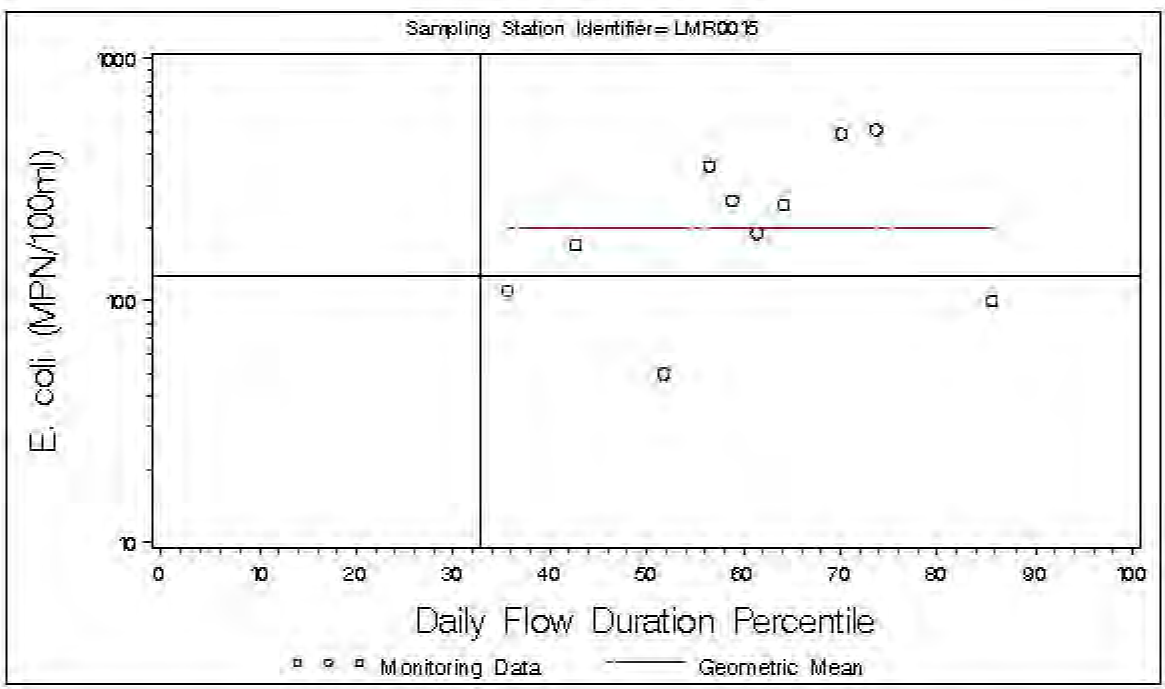

Figure B-11: *E. coli* Concentration vs. Flow Duration for Monitoring Station LMR0015 (Seasonal Condition)

APPENDIX C – BST REPORT

Maryland Department of the Environment

Identifying Sources of Fecal Pollution in Shellfish and Nontidal Waters in Maryland Watersheds

November 2006 – June 2008

Mark F. Frana, Ph.D. and Elichia A. Venso, Ph.D.
Department of Biological Sciences and Environmental Health Science
Salisbury University, Salisbury, MD

Final Report
June 30, 2008

Table of Contents

INTRODUCTION

Microbial Source Tracking. Microbial Source Tracking (MST) is a relatively recent scientific and technological innovation designed to distinguish the origins of enteric microorganisms found in environmental waters. Several different methods and a variety of different indicator organisms (both bacteria and viruses) have successfully been used for MST, as described in recent reviews (Scott *et al.*, 2002; Simpson *et al.*, 2002). When the indicator organism is bacteria, the term Bacterial Source Tracking (BST) is often used. Some common bacterial indicators for BST analysis include: *E. coli, Enterococcus* spp., *Bacteroides-Prevotella,* and *Bifidobacterium* spp.

Techniques for MST can be grouped into one of the following three categories: molecular (genotypic) methods, biochemical (phenotypic) methods, or chemical methods. Ribotyping, Pulsed-Field Gel Electrophoresis (PFGE), and Randomly-Amplified Polymorphic DNA (RAPD) are examples of molecular techniques. Biochemical methods include Antibiotic Resistance Analysis (ARA), F-specific coliphage typing, and Carbon Source Utilization (CSU) analysis. Chemical techniques detect chemical compounds associated with human activities, but do not provide any information regarding nonhuman sources. Examples of this type of technology include detection of optical brighteners from laundry detergents or caffeine (Simpson *et al.*, 2002).

Many of the molecular and biochemical methods of MST are "library-based," requiring the collection of a database of fingerprints or patterns obtained from indicator organisms isolated from known sources. Statistical analysis determines fingerprints/patterns of known sources species or categories of species (*i.e.*, human, livestock, pets, wildlife). Indicator isolates collected from water samples are analyzed using the same MST method to obtain their fingerprints or patterns, which are then statistically compared to those in the library. Based upon this comparison, the final results are expressed in terms of the "statistical probability" that the water isolates came from a given source (Simpson *et al.* 2002).

Antibiotic Resistance Analysis. A variety of different host species can potentially contribute to the fecal contamination found in natural waters. Many years ago, scientists speculated on the possibility of using resistance to antibiotics as a way of determining the sources of this fecal contamination (Bell *et al.*, 1983; Krumperman, 1983). In ARA, the premise is that bacteria isolated from different hosts can be discriminated based upon differences in the selective pressure of microbial populations found in the gastrointestinal tract of those hosts (humans, livestock, pets, wildlife) (Wiggins, 1996). Microorganisms isolated from the fecal material of wildlife would be expected to have a much lower level of resistance to antibiotics than isolates collected from the fecal material of humans, livestock and pets. In addition, depending upon the specific antibiotics used in the analysis, isolates from humans, livestock and pets could be differentiated from each other.

In ARA, isolates from known sources are tested for resistance or sensitivity against a panel of antibiotics and antibiotic concentrations. This information is then used to construct a library of antibiotic resistance patterns from known-source bacterial isolates. Microbial isolates collected from water samples are then tested and their resistance results are recorded. Based upon a comparison of resistance patterns of water and library isolates, a statistical analysis can predict the likely host source of the water isolates. (Hagedorn 1999; Wiggins 1999).

LABORATORY METHODS

Isolation of *Enterococcus* from Known-Source Samples. Fecal samples, identified to source, were delivered to the Salisbury University (SU) BST lab by Maryland Department of the Environment (MDE) personnel. Fecal material suspended in phosphate buffered saline was plated onto selective m-Enterococcus agar. After incubation at 37° C, up to eight (8) *Enterococcus* isolates were randomly selected from each fecal sample for ARA testing.

Isolation of Enterococcus from Water Samples. Water samples were collected by MDE staff and shipped overnight to MapTech Inc, Blacksburg, Va. Bacterial isolates were collected by membrane filtration. Up to 24 randomly selected *Enterococcus* isolates were collected from each water sample and all isolates were then shipped to the SU BST lab.

Antibiotic Resistance Analysis. Each bacterial isolate from both water and scat were grown in Enterococcosel® broth (Becton Dickinson, Sparks, MD) prior to ARA testing. *Enterococci* are capable of hydrolyzing esculin, turning this broth black. Only esculin-positive isolates were tested for antibiotic resistance.

Bacterial isolates were plated onto tryptic soy agar plates, each containing a different concentration of a given antibiotic. Plates were incubated overnight at 37° C and isolates then scored for growth (resistance) or no growth (sensitivity). Data consisting of a "1" for resistance or "0" for sensitivity for each isolate at each concentration of each antibiotic was then entered into a spread-sheet for statistical analysis.

The following table includes the antibiotics and concentrations used for isolates in analyses for all the study watersheds.

Table C-1: Antibiotics and concentrations used for ARA.

Antibiotic	Concentration (μg/ml)
Amoxicillin	0.625
Cephalothin	10, 15, 30, 50
Chloramphenicol	10
Chlortetracycline	60, 80, 100
Erythromycin	10
Gentamycin	5, 10, 15
Neomycin	40, 60, 80
Oxytetracycline	20, 40, 60, 80, 100
Salinomycin	10
Streptomycin	40, 60, 80, 100
Tetracycline	10, 30, 50, 100
Vancomycin	2.5

KNOWN-SOURCE LIBRARY

Construction and Use. Fecal samples (scat) from known sources in each watershed were collected during the study period by MDE personnel and delivered to the BST Laboratory at SU. *Enterococcus* isolates were obtained from known sources (e.g., human, cow, goat, horse, dog, bear, beaver, deer, duck, fox, goose, heron, opossum, rabbit, raccoon, and squirrel). For each watershed, a library of patterns of *Enterococcus* isolate responses to the panel of antibiotics was analyzed using the statistical software CART® (Salford Systems, San Diego, CA). *Enterococcus* isolate response patterns were also obtained from bacteria in water samples collected at the monitoring stations in each basin. Using statistical techniques, these patterns were then compared to those in the appropriate library to identify the probable source of each water isolate.

STATISTICAL ANALYSIS

We applied a tree classification method, [1]CART®, to build a model that classifies isolates into source categories based on ARA data. CART® builds a classification tree by recursively splitting the library of isolates into two nodes. Each split is determined by the antibiotic variables (antibiotic resistance measured for a collection of antibiotics at varying concentrations). The first step in the tree-building process splits the library into two nodes by considering every binary split associated with every variable. The split is chosen that maximizes a specified index of homogeneity for isolate sources within each of the nodes. In subsequent steps, the same process is applied to each resulting node until a *stopping* criterion is satisfied. Nodes where an additional split would lead to only an insignificant increase in the *homogeneity index* relative to the *stopping* criterion are referred to as *terminal* nodes.[2] The collection of *terminal* nodes defines the classification model. Each *terminal* node is associated with one source, the source isolate with an unknown source), based that is most populous among the library isolates in the node. Each water sample isolate (*i.e.*, an on its antibiotic resistance pattern, is identified with one specific *terminal* node and is assigned the source of the majority of library isolates in that *terminal* node.[3]

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[1] The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Hastie T, Tibshirani R, and Friedman J. Springer 2001.

[2] An ideal split, i.e., a split that achieves the theoretical maximum for homogeneity, would produce two nodes each containing library isolates from only one source.

[3] The CART® tree-classification method we employed includes various features to ensure the development of an optimal classification model. For brevity in exposition, we have chosen not to present details of those features, but suggest the following sources: Breiman L, et al. *Classification and Regression Trees*. Pacific Grove: Wadsworth, 1984; and Steinberg D and Colla P. *CART—Classification and Regression Trees*. San Diego, CA: Salford Systems, 1997.

ARA RESULTS

Liberty Reservoir Watershed ARA Results

Known-Source Library. A 621 known-source isolate library was constructed from sources in the Liberty Reservoir Watershed. The number of unique antibiotic resistance patterns was calculated, and the known sources in the combined library were grouped into four categories: human, livestock (cow, horse), pet (dog), and wildlife (deer, duck, fox, goose, rabbit, raccoon) (Table 2-LIB). The library was analyzed for its ability to take a subset of the library isolates and correctly predict the identity of their host sources when they were treated as unknowns. Average rates of correct classification (ARCC) for the library were found by repeating this analysis using several probability cutoff points, as described above. The number-not-classified for each probability was determined. From these results, the percent unknown and percent correct classification (RCCs) was calculated (Table 3-LIB).

Table 2-LIB: Liberty Reservoir. Category, total number, and number of unique patterns in the Liberty Reservoir known-source library.

Category	Potential Sources	Total Isolates	Unique Patterns
Human	human	86	59
Livestock	cow, horse	210	55
Pet	dog	109	56
Wildlife	deer, duck, fox, goose, rabbit, raccoon	216	54
Total		621	224

For Liberty Reservoir Watershed, a cutoff probability of 0.70 (70%) was shown to yield an overall rate of correct classification of 85% (Figure 1-LIB; Table 3-LIB). The resulting rates of correction classification (RCCs) for the four categories of sources in the Liberty Reservoir portion of the library are shown in Table 4-LIB.

Table 3-LIB: Liberty Reservoir. Number of isolates not classified, percent unknown, and percent correct for seven (7) cutoff probabilities for Liberty Reservoir known-source isolates using the Liberty Reservoir known-source library.

Threshold	0	0.375	0.5	0.6	**0.7**	0.8	0.9
% correct	75.2%	75.2%	75.2%	81.7%	**85.4%**	94.0%	95.5%
% unknown	0.0%	0.0%	0.8%	19.2%	**32.9%**	59.6%	68.1%
# not classified	0	0	5	119	**204**	370	423

Figure 1-LIB. Liberty Reservoir Classification Model: Percent Correct versus Percent Unknown using the Liberty Reservoir library.

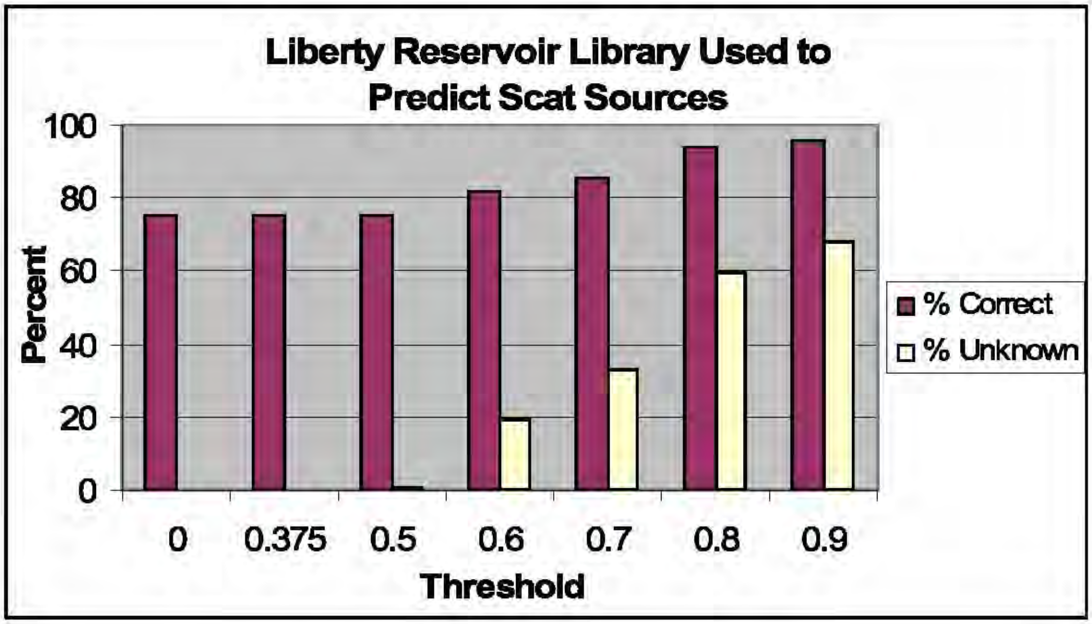


Table 4-LIB: Liberty Reservoir. Actual species categories versus predicted categories, at 70% probability cutoff, with rates of correct classification (RCC) for each category.

	Predicted						
Actual	Human	Livestock	Pet	Wildlife	Unknown	Total	RCC*
Human	58	1	7	1	19	86	86.6%
Livestock	3	96	4	33	74	210	70.6%
Pet	2	0	68	2	37	109	94.4%
Wildlife	2	6	0	134	74	216	94.4%
Total	65	103	79	170	204	621	85.4%

*RCC = Actual number of predicted species category / Total number predicted. Example: 163 pet correctly predicted / 175 total number predicted for pet = 163/175 = 95%.

Liberty Reservoir Water Samples. Monthly monitoring from five (5) monitoring stations on Liberty Reservoir was the source of water samples. The maximum number of *Enterococcus* isolates per water sample was 24, although the number of isolates that actually grew was sometimes less than 24. A total of 1,159 *Enterococcus* isolates were analyzed by statistical analysis. The BST results by species category, shown in Table 5-LIB, indicate that 74% of the water isolates were able to be classified to a probable host source when using a 0.70 (70%) probability threshold.

Table 5-LIB: Liberty Reservoir. Probable host sources of water isolates by species category, number of isolates, and percent isolates classified at a cutoff probability of 70%.

Source	Count	Percent	Percent Without Unknowns
Human	233	20.1%	27.3%
Livestock	230	19.8%	27.0%
Pet	122	10.5%	14.3%
Wildlife	267	23.0%	31.3%
Unknown	307	26.5%	
Total	1159	100.0%	100.0%
% classified	**73.5%**		

*Percentages may not add up to 100% due to rounding.

The seasonal distribution of water isolates from samples collected at each sampling station is shown below in Table 6-LIB.

Table 6-LIB: Liberty Reservoir. *Enterococcus* isolates obtained from water collected during the spring, summer, fall, and winter seasons for Liberty Reservoir's five (5) monitoring stations.

	Season				
Station	Spring	Summer	Fall	Winter	Total
BEA0006	51	71	67	38	227
LMR0015	67	71	72	18	228
MDE0026	72	72	67	44	255
MOR0040	70	71	61	17	219
NPA0165	62	72	68	28	230
Total	322	357	335	145	1159

Tables 7-LIB and 8-LIB on the following pages show the number and percent of the probable sources for each monitoring station by month.

Table 7-LIB: Liberty Reservoir. BST Analysis: Number of Isolates per Station per Date.

			Predicted	Source			
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
BEA0006	11/19/03	2	5	4	5	4	20
BEA0006	12/03/03	5	6	3	1	9	24
BEA0006	01/05/04	0	3	3	2	11	19
BEA0006	02/17/04	7	4	1	1	4	17
BEA0006	03/01/04	1	0	0	0	1	2
BEA0006	04/05/04	3	5	1	2	7	18
BEA0006	05/10/04	2	3	0	4	0	9
BEA0006	06/07/04	6	4	5	5	4	24
BEA0006	07/06/04	12	1	2	4	4	23
BEA0006	08/09/04	8	0	1	12	3	24
BEA0006	09/07/04	3	5	1	5	10	24
BEA0006	10/04/04	6	0	6	3	8	23
LMR0015	11/19/03	0	10	0	6	8	24
LMR0015	12/03/03	0	7	6	6	5	24
LMR0015	01/05/04	0	4	1	1	3	9
LMR0015	02/17/04	0	4	0	2	1	7
LMR0015	03/01/04	0	0	0	1	1	2
LMR0015	04/05/04	1	8	1	4	5	19
LMR0015	05/10/04	3	10	0	4	7	24
LMR0015	06/07/04	0	4	0	9	11	24
LMR0015	07/06/04	4	0	1	15	3	23
LMR0015	08/09/04	3	2	0	8	11	24
LMR0015	09/07/04	1	10	11	1	1	24
LMR0015	10/04/04	1	3	6	7	7	24
MDE0026	11/19/03	3	6	3	2	8	22
MDE0026	12/03/03	8	2	2	6	6	24
MDE0026	01/05/04	0	8	2	6	6	22
MDE0026	02/17/04	4	5	1	1	4	15
MDE0026	03/01/04	2	1	2	1	1	7
MDE0026	04/05/04	11	5	2	0	6	24
MDE0026	05/10/04	9	6	1	4	4	24
MDE0026	06/07/04	4	3	6	8	3	24
MDE0026	07/06/04	13	0	10	1	0	24
MDE0026	08/09/04	6	0	1	9	8	24
MDE0026	09/07/04	0	4	2	5	13	24
MDE0026	10/04/04	2	3	2	7	7	21

Table 7-LIB: Liberty Reservoir (continued). BST Analysis: Number of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
MOR0040	11/19/03	1	5	0	3	6	15
MOR0040	12/03/03	6	4	1	2	11	24
MOR0040	01/05/04	0	1	0	6	1	8
MOR0040	02/17/04	1	0	3	1	2	7
MOR0040	03/01/04	0	1	0	0	1	2
MOR0040	04/05/04	1	7	1	8	6	23
MOR0040	05/10/04	12	2	1	8	0	23
MOR0040	06/07/04	1	3	1	7	12	24
MOR0040	07/06/04	7	1	8	3	4	23
MOR0040	08/09/04	3	2	0	4	15	24
MOR0040	09/07/04	3	6	1	5	9	24
MOR0040	10/04/04	8	1	2	7	4	22
NPA0165	11/19/03	2	1	1	14	3	21
NPA0165	12/03/03	11	5	0	5	3	24
NPA0165	01/05/04	2	4	0	1	5	12
NPA0165	02/17/04	0	7	1	2	3	13
NPA0165	03/01/04	0	2	0	0	1	3
NPA0165	04/05/04	1	16	2	0	5	24
NPA0165	05/10/04	4	5	0	1	5	15
NPA0165	06/07/04	3	11	1	2	6	23
NPA0165	07/06/04	9	2	4	5	4	24
NPA0165	08/09/04	12	1	1	9	1	24
NPA0165	09/07/04	6	2	0	13	3	24
NPA0165	10/04/04	10	0	7	3	3	23
Total		233	230	122	267	307	1159

Table 8-LIB: Liberty Reservoir. BST Analysis: Percent of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
BEA0006	11/19/03	10%	25%	20%	25%	20%	100%
BEA0006	12/03/03	21%	25%	13%	4%	38%	100%
BEA0006	01/05/04	0%	16%	16%	11%	58%	100%
BEA0006	02/17/04	41%	24%	6%	6%	24%	100%
BEA0006	03/01/04	50%	0%	0%	0%	50%	100%
BEA0006	04/05/04	17%	28%	6%	11%	39%	100%
BEA0006	05/10/04	22%	33%	0%	44%	0%	100%
BEA0006	06/07/04	25%	17%	21%	21%	17%	100%
BEA0006	07/06/04	52%	4%	9%	17%	17%	100%
BEA0006	08/09/04	33%	0%	4%	50%	13%	100%
BEA0006	09/07/04	13%	21%	4%	21%	42%	100%

BEA0006	10/04/04	26%	0%	26%	13%	35%	100%

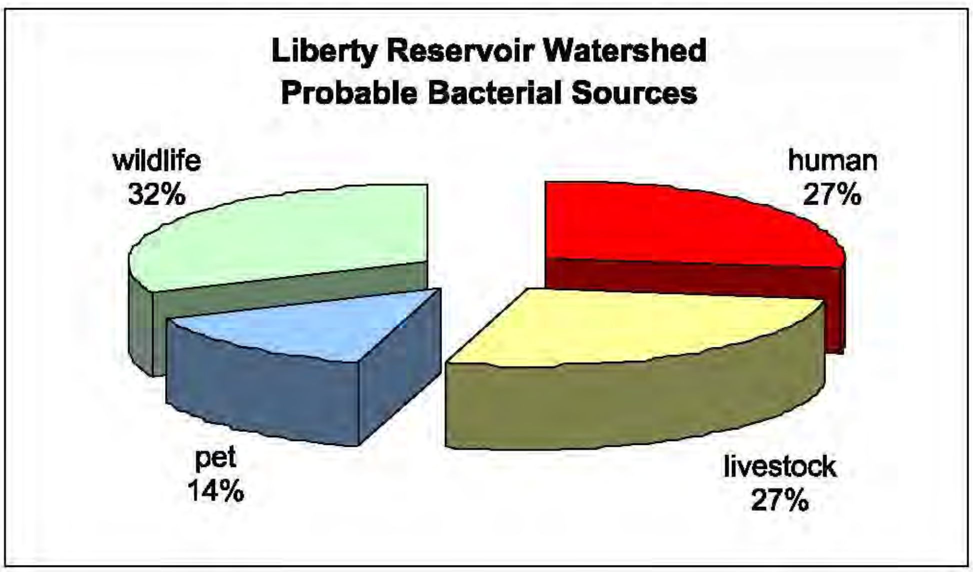
Table 8-LIB: Liberty Reservoir (continued). BST Analysis: Percent of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
LMR0015	11/19/03	0%	42%	0%	25%	33%	100%
LMR0015	12/03/03	0%	29%	25%	25%	21%	100%
LMR0015	01/05/04	0%	44%	11%	11%	33%	100%
LMR0015	02/17/04	0%	57%	0%	29%	14%	100%
LMR0015	03/01/04	0%	0%	0%	50%	50%	100%
LMR0015	04/05/04	5%	42%	5%	21%	26%	100%
LMR0015	05/10/04	13%	42%	0%	17%	29%	100%
LMR0015	06/07/04	0%	17%	0%	38%	46%	100%
LMR0015	07/06/04	17%	0%	4%	65%	13%	100%
LMR0015	08/09/04	13%	8%	0%	33%	46%	100%
LMR0015	09/07/04	4%	42%	46%	4%	4%	100%
LMR0015	10/04/04	4%	13%	25%	29%	29%	100%
MDE0026	11/19/03	14%	27%	14%	9%	36%	100%
MDE0026	12/03/03	33%	8%	8%	25%	25%	100%
MDE0026	01/05/04	0%	36%	9%	27%	27%	100%
MDE0026	02/17/04	27%	33%	7%	7%	27%	100%
MDE0026	03/01/04	29%	14%	29%	14%	14%	100%
MDE0026	04/05/04	46%	21%	8%	0%	25%	100%
MDE0026	05/10/04	38%	25%	4%	17%	17%	100%
MDE0026	06/07/04	17%	13%	25%	33%	13%	100%
MDE0026	07/06/04	54%	0%	42%	4%	0%	100%
MDE0026	08/09/04	25%	0%	4%	38%	33%	100%
MDE0026	09/07/04	0%	17%	8%	21%	54%	100%
MDE0026	10/04/04	10%	14%	10%	33%	33%	100%
MOR0040	11/19/03	7%	33%	0%	20%	40%	100%
MOR0040	12/03/03	25%	17%	4%	8%	46%	100%
MOR0040	01/05/04	0%	13%	0%	75%	13%	100%
MOR0040	02/17/04	14%	0%	43%	14%	29%	100%
MOR0040	03/01/04	0%	50%	0%	0%	50%	100%
MOR0040	04/05/04	4%	30%	4%	35%	26%	100%
MOR0040	05/10/04	52%	9%	4%	35%	0%	100%
MOR0040	06/07/04	4%	13%	4%	29%	50%	100%
MOR0040	07/06/04	30%	4%	35%	13%	17%	100%
MOR0040	08/09/04	13%	8%	0%	17%	63%	100%
MOR0040	09/07/04	13%	25%	4%	21%	38%	100%
MOR0040	10/04/04	36%	5%	9%	32%	18%	100%
NPA0165	11/19/03	10%	5%	5%	67%	14%	100%
NPA0165	12/03/03	46%	21%	0%	21%	13%	100%
NPA0165	01/05/04	17%	33%	0%	8%	42%	100%
NPA0165	02/17/04	0%	54%	8%	15%	23%	100%
NPA0165	03/01/04	0%	67%	0%	0%	33%	100%

Table 8-LIB: Liberty Reservoir (continued). BST Analysis: Percent of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
NPA0165	04/05/04	4%	67%	8%	0%	21%	100%
NPA0165	05/10/04	27%	33%	0%	7%	33%	100%
NPA0165	06/07/04	13%	48%	4%	9%	26%	100%
NPA0165	07/06/04	38%	8%	17%	21%	17%	100%
NPA0165	08/09/04	50%	4%	4%	38%	4%	100%
NPA0165	09/07/04	25%	8%	0%	54%	13%	100%
NPA0165	10/04/04	43%	0%	30%	13%	13%	100%
Total		20%	20%	11%	23%	26%	100%

Figure 2-LIB: Liberty Reservoir Watershed relative contributions by probable sources of *Enterococcus* contamination.



SUMMARY

Liberty Reservoir Summary

The use of ARA was successful for identification of probable bacterial sources in the Liberty Reservoir Watershed. When water isolates were compared to the library and potential sources predicted, 74% of the isolates were classified as to category by statistical analysis. The highest RCC for the library was 94% (for pet and wildlife), with 87% for human. Livestock had an RCC of 71%.

The largest category of potential sources in the watershed as a whole was wildlife (32% of classified water isolates), followed by human and livestock (27% each). The last potential source contribution was for pet (14%) (Fig. 2-LIB).

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Adjustment of BST Results

As explained in the BST Summary for the Liberty Reservoir watershed, the percent of correct classification (RCC) for bacteria sources, especially for the livestock category can introduce a potential misclassification of the more probable sources in the watershed. This is seen in Table C-4, which shows results of the analysis of samples from known sources. For example, out of 621, 86 isolates were known to be of human source but only 58 were classified by the analysis as being of human source. Of those 86, one isolate was classified as wildlife, 7 as pet, 1 as livestock, and 19 as unknown. Similarly, of the other three categories, three isolates were known to be livestock, two isolates known to be from pets, and 2 isolates from wildlife were classified as human, resulting in a total of 65 of all 621 isolates classified as human of which only 58 were known to be of human source.

The results provided by the BST methodology can be adjusted based on the known source percent of correct classification results provided in Table C-4.

Example:

The current BST methodology provides the following source percentages for station BEA0016 during high flow conditions:

Source Category	Original Percentage
Pets	10.92%
Human	22.17 %
Livestock	22.06 %
Wildlife	16.90 %
Unknown	27.95 %

To get the correct human source percentage we redistributed the above percentages based on the % of correct classification as follows.

From Table C-4:

Source Category	Isolates known to be from Human Source	Total Isolates Predicted for Each category	Percentage
Pets	7	79	8.9%
Human	58	65	89.2%
Livestock	1	103	1.0%
Wildlife	1	170	0.6%
Unknown	19	204	9.3%
Total	86	621	13.8%

Applying those percentages to the original estimated source distribution presented above will result in the adjusted percentage for human sources:

= (8.9 x 10.92) + (89.2 x 22.17) + (1.0 x 22.06) + (0.6 x 16.90) + (9.3 x 16.90) = 23.7 %

Thus the correct human source percentage, the value used in the TMDL analysis, is 23.7% and not 22.17%. Corrected percentages are also calculated as above for domestic animal, livestock and wildlife sources. The classification of unknown is eliminated in the process as all known isolates are of known source. For station BEA0016 during high flow condition the corrected source percentages are as follows:

Source Category	Adjusted Percentage
Pets	15.3 %
Human	23.7 %
Livestock	35.6 %
Wildlife	25.4 %

APPENDIX D – ESTIMATING MAXIMUM DAILY LOADS

This appendix documents the technical approach used to define maximum daily loads of fecal bacteria consistent with the annual average TMDL which, when met, are protective of water quality standards in the Liberty Reservoir watershed. The approach builds upon the TMDL analysis that was conducted to ensure that compliance with the annual average target will result in compliance with the applicable water quality standards. The annual average loading target was converted into allowable *daily* values by using the loadings developed from the TMDL analysis. The approach is consistent with available EPA guidance on generating daily loads for TMDLs.

The available guidance for developing daily loads does not specify a single allowable approach; it contains a range of options. Selection of a specific method for translating a time-series of allowable loads into expression of a TMDL requires decisions regarding both the level of resolution (e.g., single daily load for all conditions vs. loads that vary with environmental conditions) and level of probability associated with the TMDL.

Level of Resolution

The level of resolution pertains to the amount of detail used in specifying the maximum daily load. The draft EPA guidance on daily loads provides three categories of options for level of resolution.

1. **Representative daily load:** In this option, a single daily load (or multiple representative daily loads) is specified that covers all time periods and environmental conditions.
2. **Flow-variable daily load:** This option allows the maximum daily load to vary based upon the observed flow condition.
3. **Temporally-variable daily load:** This option allows the maximum daily load to vary based upon seasons or times of varying source or water body behavior.

Probability Level

Essentially all TMDLs have some probability of being exceeded, with the specific probability being either explicitly specified or implicitly assumed. This level of probability reflects, directly or indirectly, two separate phenomena:

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often conditions can allowably surpass the combined magnitude and duration components.
2. Pollutant loads, especially from wet weather sources, typically exhibit a large degree of variability over time. It is rarely practical to specify a "never to be exceeded value" for a daily load, as essentially any loading value has some finite probability of being exceeded.

The draft daily load guidance states that the probability component of the maximum daily load should be "based on a representative statistical measure" that is dependent upon the specific TMDL and best professional judgment of the developers. This statistical measure represents how often the maximum daily load is expected/allowed to be exceeded. The primary options for selecting this level of protection would be:

1. **The maximum daily load reflects some central tendency:** In this option, the maximum daily load is based upon the mean or median value of the range of loads expected to occur. The variability in the actual loads is not addressed.
2. **The maximum daily load reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the maximum daily load is based upon the allowable load that is predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence.
3. **The maximum daily load is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the maximum daily load based upon a characterization of the variability of daily loads. For example, selection of the 95^{th} percentile value would result in a maximum daily load that would be exceeded 5% of the time.

Selected Approach for Defining Maximum Daily Loads for Nonpoint Sources and MS4

To calculate the Liberty Reservoir basin MDL for nonpoint sources and MS4s, a "representative daily load" option was selected as the level of resolution, and a value "that will be exceeded with a pre-defined probability" was selected as the level of protection. In these options, the maximum daily load is one single daily load that covers the two flow strata, with an upper bound percentile that accounts for the variability of daily loads. The upper bound percentile and the maximum daily loads were estimated following EPA's "Technical Support Document for Water Quality-Based Toxics Control" (1991 TSD) (EPA 1991); and "Approaches For Developing a Daily Load Expression for TMDLs Computed for Longer Term Averages" (EPA 2006).

The 1991 TSD illustrates a way to identify a target maximum daily concentration from a long-term average concentration (LTA) based on a coefficient of variation (CV) and the assumption of a log-normal distribution of the data. The equations for determining both the upper boundary percentile and corresponding maximum daily load described in the TSD are as follows:

$$MDLC = LTA * e^{[Z\sigma - 0.5\sigma^2]} \qquad \text{(D1)}$$

and,

$$\text{MDL} = \text{MDLC*Q*F} \qquad \text{(D2)}$$

where,

MDLC = maximum daily load concentration (MPN/100ml)
LTAC = long-term average TMDL concentration (MPN/100ml)
MDL = Maximum Daily Load (MPN/day)
Z = z-score associated with upper bound percentile (unitless)

σ^2 $= \ln(CV^2 + 1)$
CV = coefficient of variation
Q = flow (cfs)
F = conversion factor

The first step is to use the bacteria monitoring data to estimate the upper bound percentile as the percentile of the highest observed bacteria concentration in each of the four monitoring stations of the Liberty Reservoir basin. Using the maximum value of *E. coli* observed in each monitoring station, and solving for the z-score using the above formula, the value of "z" and its corresponding percentile is found as shown below. The percentile associated with the particular value of z can be found in tables in statistics books or using the function NORMSINV(%) in EXCEL©.

$$Z = [\log_{10}(MOC) - \log(AM) + 0.5\sigma^2]/\sigma \qquad (D3)$$

where,

Z = z-score associated with upper bound percentile
MOC = maximum observed bacteria concentration (MPN/100ml)
AM = arithmetic mean observed bacteria concentrations (MPN/100ml)
σ^2 $= \ln(CV^2 + 1)$
CV = coefficient of variation (arithmetic)

Note that these equations use arithmetic parameters, not geometric parameters as used in the calculations of the long-term annual average TMDL. Therefore, bias correction factors are not necessary to estimate the loads as will be explained below.

The highest percentile of all the stations analyzed by stratum will define the upper bound percentile to be used in estimating the maximum daily limits. In the case of Liberty Reservoir basin, a value measured during high flow conditions at the MDE0026 station resulted in the highest percentile of both strata of the five stations. This value translates to the 99.7^{th} percentile, which is the upper boundary percentile to be used in the computation of the maximum daily limits (MDLs) throughout this analysis. Results of the analysis to estimate the recurrence or upper boundary percentile are shown in Table D-1.

Table D-1: Percentiles of Maximum Observed Bacteria Concentrations

Subwatershed	Flow Stratum	Maximum Observed *E. coli* Concentration (MPN/100ml)	Percentile (%)
NPA0165 North Branch Patapsco River	**High**	9,800	99.6
	Low	5,800	98.5
BEA0016 Beaver Run	**High**	930	98.0
	Low	4,400	98.9
MDE0026 Middle Run	**High**	24,190	99.7
	Low	1,670	94.9
MOR0040 Morgan Run	**High**	1,990	99.1
	Low	960	94.8
LMR0015 Little Morgan Run	**High**	1,330	99.2
	Low	620	88.2

The 99.7th percentile value results in a maximum daily load that would not be exceeded 99.7% of the time, as, in a similar manner, a TMDL that represents the long-term average condition would be expected to be exceeded half the time even after all required controls were implemented.

The MDLCs are estimated based on a statistical methodology referred to as "Statistical Theory of Rollback (STR)". This method predicts concentrations of a pollutant after its sources have been controlled (post-control concentrations), in this case after annual average TMDL implementation. Using STR, the daily TMDLs are calculated as presented below.

First, the long-term average TMDL concentrations (C_{LTA}) by stratum are estimated by applying the required percent reduction to the baseline (monitoring data) concentrations (C_b) by stratum as follows:

From Section 4.3, equations (8) and (9):

$$L_b = L_{b\text{-}H} + L_{b\text{-}L}$$

$$L_b = Q_H*C_{bH}*F_{1H}*W_H + Q_L*C_{bL}*F_{1L}*W_L$$

And from equation (10):

$$Annual\ Average\ TMDL = L_b*(1-R)$$

Therefore,

$$L_b*(1\text{-}R) = Q_H*C_H*F_{1H}*W_H*(1\text{-}R) + Q_L*C_L*F_{1L}*W_L*(1\text{-}R) \qquad \text{(D4)}$$

As explained before, a reduction in concentration is proportional to a reduction in load, thus the bacteria concentrations expected after reductions are applied are equal to the baseline concentrations multiplied by one minus the required reduction:

$$C_{LTA\text{-}H} = C_{b\text{-}H}*(1\text{-}R_H) \qquad \text{(D5)}$$

$$C_{LTA\text{-}L} = C_{b\text{-}L}*(1\text{-}R_L) \qquad \text{(D6)}$$

The TMDL concentrations estimated as explained above are shown in Table D-2.

Table D-2: Long-term Annual Average (LTA) TMDL Bacteria Concentrations

Subwatershed	Flow Stratum	LTA Geometric Mean *E. coli* Concentration (MPN/100ml)	LTA Arithmetic Mean* *E. coli* Concentration (MPN/100ml)
NPA0165 North Branch Patapsco River	**High**	30	127
	Low	95	122
BEA0016 Beaver Run	**High**	34	69
	Low	85	209
MDE0026 Middle Run	**High**	43	182
	Low	105	134
MOR0040 Morgan Run	**High**	47	135
	Low	94	199
LMR0015 Little Morgan Run	**High**	24	68
	Low	95	184

*Only arithmetic parameters are used in the daily loads analysis.

The next step is to calculate the 99.7th percentile (the MDL concentrations) of these expected concentrations (LTA concentrations) using the coefficient of variation of the baseline concentrations. Based on a general rule for coefficient of variations, the coefficient of variation of the distribution of pollutant concentrations does not change after these concentrations have been reduced or controlled by a fixed proportion (Ott 1995). Therefore, the coefficient of variation estimated using the monitoring data concentrations does not change, and it can be used to estimate the 99.7th percentile of the long-term average TMDL concentrations (LTAC) using equation (D1). These values are shown in Table D-3.

Table D-3: Maximum Daily Load (MDL) Concentrations

Subwatershed	Flow Stratum	Coefficient of Variation	MDL *E. coli* Concentration (MPN/100ml)
NPA0165 North Branch Patapsco River	**High**	4.10	3,282
	Low	2.12	3,504
BEA0016 Beaver Run	**High**	1.76	911
	Low	2.25	3,483
MDE0026 Middle Run	**High**	4.15	4,751
	Low	0.79	720
MOR0040 Morgan Run	**High**	2.70	2,618
	Low	1.85	2,758
LMR0015 Little Morgan Run	**High**	2.65	1,295
	Low	1.66	2,296

With the 99.7th percentiles of LTA TMDL bacteria concentrations estimated for both high flow and low flow strata as explained above, the maximum daily load for MS4 and nonpoint sources for each subwatershed can be now estimated as:

$$\textit{Daily TMDL (MPN/day)} = Q_H*(99.7^{th}C_{LTA\text{-}H})*F_{IH}*W_H + Q_L*(99.7^{th}C_{LTA\text{-}L})*F_{IL}*W_L \qquad \text{(D7)}$$

Selected Approach for Defining Maximum Daily Loads for Other Point Sources

The TMDL also considers contributions from other point sources (i.e., municipal and industrial WWTP) in watersheds that have NPDES permits with fecal bacteria limits. The TMDL analysis that defined the average annual TMDL held each of these sources constant at their existing NPDES permit limit (daily or monthly) for the entire year. The approach used to determine maximum daily loads was dependent upon whether a maximum daily load was specified within the permit. If a maximum daily load was specified within the permit, then the maximum design flow is multiplied by the maximum daily limit to obtain a maximum daily load. If a maximum daily limit was not specified in the permit, then the maximum daily loads are calculated from guidance in the TSD for Water Quality-based Toxics Control (EPA 1991). The long-term average annual TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99th percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual bacteria loads for WWTPs are reported in billion MPN/year. In the Liberty Reservoir watershed, to estimate the maximum daily loads for WWTPs, the annual average loads are multiplied by the multiplication factor as follows:

$$WWTP\text{-}WLA\ MDL\ _{(billion\ MPN/day)} = [WWTP\text{-}WLA\ _{(billion\ MPN/year)}]*(3.11/365) \quad \text{(D8)}$$

The Maximum Daily Loads for the Liberty Reservoir subwatersheds are presented in Table D-4 below. For the unmonitored downstream subwatershed an average of the five upstream station loads is used.

Table D-4: Maximum Daily Loads Summary

Subwatershed	Flow Stratum	Maximum Daily Load (Billion *E. coli* MPN/day)	
		by Stratum	Weighted by Stratum
NPA0165 North Branch Patapsco River	**High**	10,981	5,586
	Low	3,082	
BEA0016 Beaver Run	**High**	756	779
	Low	789	
MDE0026 Middle Run	**High**	1,721	594
	Low	71	
MOR0040 Morgan Run	**High**	4,727	2,330
	Low	1,217	
LMR0015 Little Morgan Run	**High**	590	362
	Low	256	
Downstream Subwatershed	**High**	3,755	1,930
	Low	1,083	

Maximum Daily Loads Allocations

Using the MDLs estimated as explained above, loads are allocated following the same methodology as the annual average TMDL (See section 4.8). The maximum daily load allocations for the Liberty Reservoir basin are presented in Table D-5.

Table D-5: Maximum Daily Loads

Subwatershed	Total Allocation	LA	SW-WLA	WWTP-WLA
	(Billion MPN *E. coli* /year)			
NPA0165	5,586	5,434	143	9
BEA0016	779	764	14	0
MDE0026	594	592	2	0
MOR0040	2,330	2,328	2	0
LMR0015	362	323	39	0
Downstream Subwatershed	1,930	1,854	76	0
***MDL*[1]**	**11,580**	**11,295**	**276**	**9**

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APPENDIX H:

Water Quality Analysis of Chromium and Lead for the Liberty Reservoir Impoundment in Baltimore and Carroll Counties, Maryland

Water Quality Analysis of Chromium and Lead for the Liberty Reservoir Impoundment in Baltimore and Carroll Counties, Maryland

FINAL

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List of Abbreviations

CBL	Chesapeake Biological Laboratory
cm	Centimeter
COMAR	Code of Maryland Regulations
Cr	Chromium
CWA	Clean Water Act
DOC	Dissolved Organic Carbon
EPA	Environmental Protection Agency
HAC	Hardness Adjusted Criteria
MDE	Maryland Department of the Environment
mg	Milligram
mg/l	Milligrams per Liter
NPDES	National Pollution Discharge Elimination System
Pb	Lead
SCS	Soil Conservation Service
SSURGO	Soil Survey Geographic
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WER	Water Effects Ratio
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
µg/l	Micrograms per Liter

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

The Liberty Reservoir (basin code 02-13-09-07), located in Baltimore and Carroll Counties, MD, was identified on the State's list of WQLSs as impaired by chromium (Cr) (1996 listing), lead (Pb) (1996 listing), nutrients (1996 listing), suspended sediments (1996 listing), fecal coliform (2002 listing), methylmercury (2002 listing) and evidence of biological impacts (2002 listing). The Cr, Pb, nutrients, suspended sediment and methylmercury impairments were listed for the impoundment, and the fecal coliform and biological impairments were listed for the non-tidal streams. This report provides an analysis of recent monitoring data, including hardness data, which shows that the aquatic life criteria for Cr and Pb and the designated uses supported by those criteria are being met in the Liberty Reservoir. The non-tidal streams are not listed for Cr or Pb, therefore they are not addressed in the water quality analysis (WQA). The analysis supports the conclusion that TMDLs for Cr and Pb are not necessary to achieve water quality standards in this case because the standards are already being met. Barring the receipt of any contradictory data, this report will be used to support the removal of the Liberty Reservoir impoundment from Maryland's list of WQLSs for Cr and Pb when the Maryland Department of the Environment (MDE) proposes the revision of Maryland's 303(d) list for public review in the future. A TMDL for methyl mercury in fish tissue was completed in 2002. The nutrient, suspended sediments, fecal coliform and biological impairments will be addressed separately at a future date.

Although the waters of the Liberty Reservoir do not display signs of toxic impairments due to Cr or Pb, the State reserves the right to require additional pollution controls in the Liberty Reservoir watershed if evidence suggests that Cr or Pb from the basin are contributing to downstream water quality problems.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and U.S. Environmental Protection Agency (EPA)'s implementing regulations direct each State to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. This list of impaired waters is commonly referred to as the "303(d) list". For each WQLS, the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met.

A segment identified as a WQLS may not require the development and implementation of a TMDL if current information contradicts the previous finding of an impairment. The most common factual scenarios obviating the need for a TMDL are as follows: 1) more recent data indicating that the impairment no longer exists (i.e., water quality criteria are being met); 2) more recent and updated water quality modeling demonstrates that the segment is now attaining criteria; 3) refinements to water quality criteria, or the interpretation of those standards, which result in criteria being met; or 4) correction to errors made in the initial listing.

The Liberty Reservoir (basin code 02-13-09-07) was first identified on the 1996 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE) as impaired by chromium (Cr), lead (Pb), suspended sediments and nutrients, with fecal coliform, methylmercury and biological impairments added to the list in 2002. The Cr, Pb, nutrients, suspended sediment and methylmercury impairments were listed for the impoundment, and the fecal coliform and biological impairments were listed for the non-tidal streams. The initial listings for Cr and Pb were questionable because: 1) the original listing was based on total recoverable metals (current standard is based on dissolved metals); 2) inappropriate sampling techniques were applied (lack of filtration); 3) supporting data needed to interpret criteria was not available (hardness); and 4) a default hardness of 100 mg/L was used to convert and relate the total recoverable metals to the dissolved criteria, which superceded the total recoverable metals criteria. A water quality analysis (WQA) of Cr and Pb in the Liberty Reservoir impoundment was performed using recent water column and sediment toxicity data. Results show no impairment for Cr or Pb. The non-tidal streams are not listed for Cr or Pb therefore they are not addressed in the WQA. A TMDL for methylmercury in fish tissue was completed in 2002. The nutrient, suspended sediments, fecal coliform and biological impairments will be addressed separately at a future date.

The remainder of this report lays out the general setting of the waterbody within the Liberty Reservoir watershed, presents a discussion of the water quality characterization process, and provides conclusions with regard to the characterization. The most recent data establishes that the Liberty Reservoir is achieving water quality standards for Cr and Pb.

2.0 GENERAL SETTING

The Liberty Reservoir watershed is located in the Patapsco region of the Chesapeake Bay watershed within Maryland (see Figure 1). The watershed covers portions of Baltimore and Carroll County. The watershed area covers 104,800 acres. The Reservoir is owned by the Baltimore City Department of Public Works and is situated in the Patapsco River watershed. The dam was constructed in 1953.

Inflow to Liberty Reservoir is primarily via the northern branch of the Patapsco River with additional inflow from Morgan Run and several small tributaries. Discharge from the reservoir is into the Lower North Branch of the Patapsco River. The reservoir is currently used for recreational activities (swimming, fishing and boating) and as a major water supply for the City of Baltimore. Upstream watershed usage includes a water supply for the Carroll County Department of Public Works, an unnamed park surrounding the reservoir and Soldiers Delight Natural Environmental area. Downstream usage includes Patapsco Valley State Park. The physical characteristics of the Liberty Reservoir are shown in Table 1.

Table 1: Physical Characteristics of the Liberty Reservoir

Location:	Baltimore County, Maryland Latitude 39.28 Longitude 76.89 (Dam)
Surface Area:	12.6 km^2
Normal Depth:	40.5 m
Normal Volume:	$1.63 * 10^8$ m^3
Drainage Area to Lake:	424.1 km^2
Average Annual Flow:	5.5 m^3/s

The Liberty Reservoir watershed lies within the Piedmont province of Central Maryland. The Piedmont province is characterized by gentle to steep rolling topography, low hills and ridges. The surficial geology is characterized by crystalline rocks of volcanic origin consisting primarily of schist and gneiss. These formations are resistant to short-term erosion and often determine the limits of stream bank and stream bed. These crystalline formations decrease in elevation from northwest to southeast and eventually extend beneath the younger sediments of the Coastal Plain. (Coastal Environmental Services, 1995).

The Liberty Reservoir watershed drains from northwest to southeast, following the dip of the underlying crystalline bedrock in the Piedmont province. The surface elevations range from approximately 980 feet to 420 feet at the Liberty Reservoir Spillway. Stream channels of the sub-watersheds are well incised in the Eastern Piedmont, and exhibit relatively straight reaches and sharp bends, reflecting their tendency to following zones of fractured or weathered rock. (Coastal Environmental Services, 1995).

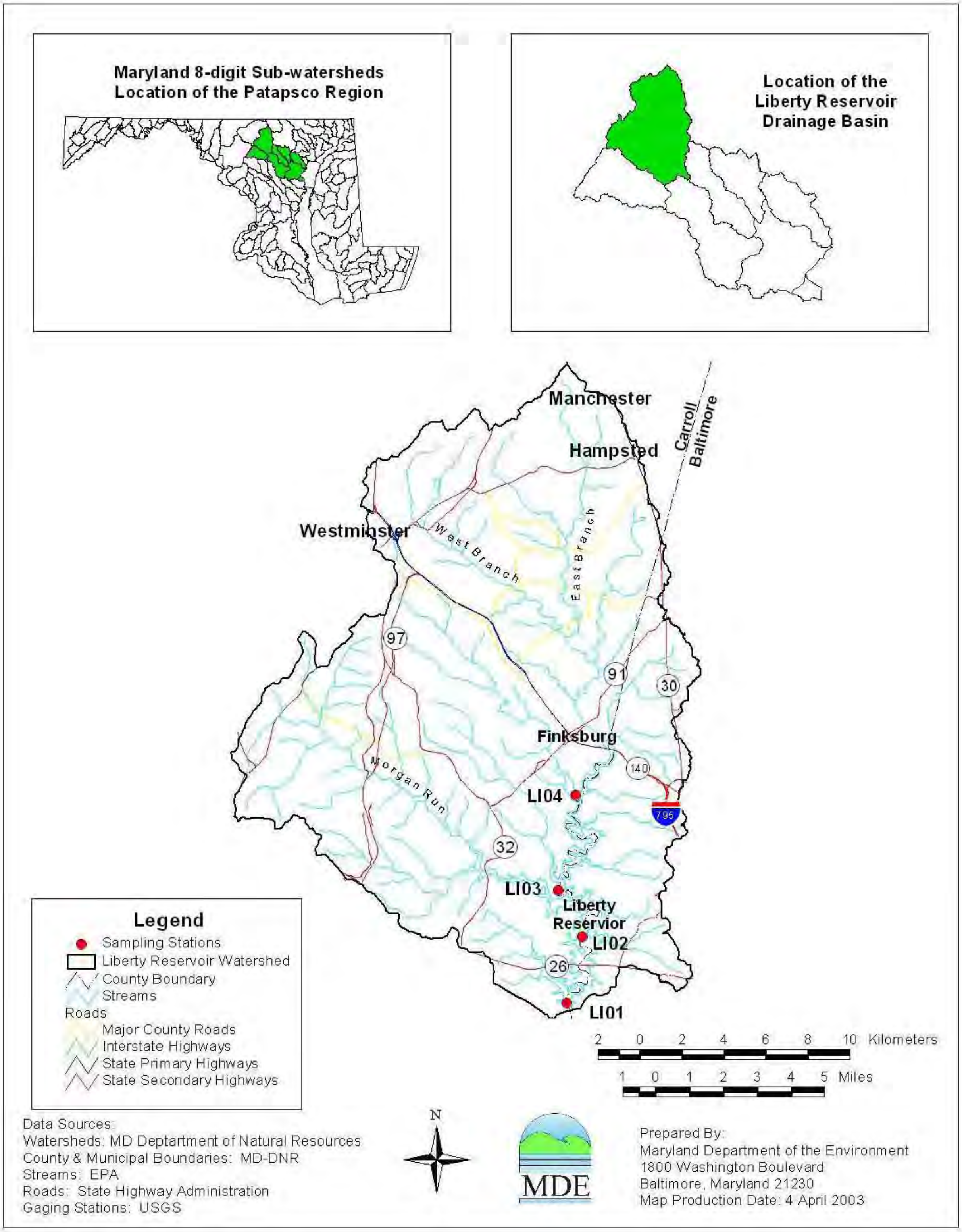

Figure 1: Watershed Map of the Liberty Reservoir

The watershed is comprised primarily of A and B type soils. Soil type is categorized by four hydrologic soil groups developed by the Soil Conservation Service (SCS). The definitions of the groups are as follows (SCS, 1976):

> Group A: Soils with high infiltration rates, typically deep well-drained to excessively drained sands or gravels.
> Group B: Soils with moderate infiltration rates, generally moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
> Group C: Soils with slow infiltration rates, mainly soils with a layer that impedes downward water movement or soils with moderately fine to fine texture.
> D: Soils with very slow infiltration rates, mainly clay soils, soils with a permanently high water table, and shallow soils over nearly impervious material.

The soil distribution within the watershed is approximately 22.3% soil group A, 63.0% soil group B, 7.4% soil group C and 7.3% soil group D. Soil Data was obtained from Soil Survey Geographic (SSURGO) coverages created by the National Resources Conservation Service.

Land use within the Liberty Reservoir watershed is a mixture of agricultural, urban and forestland (see Figure 2). No major point sources discharge Cr or Pb within the watershed. The land use distribution in the watershed is approximately 41% agricultural, 31% forest/herbaceous, 25% urban and 3% water (Maryland Department of Planning, 2000).

3.0 WATER QUALITY CHARACTERIZATION

A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody. Maryland's water quality standards presently include numeric criteria for metals and other toxic substances based on the need to protect aquatic life, wildlife and human health. Water quality standards for toxic substances also address sediment quality to ensure the bottom sediment of a waterbody is capable of supporting aquatic life, thus protecting the designated uses.

The Maryland Surface Water Use Designation (Code of Maryland Regulations (COMAR) 26.08.02.08J) for the Liberty Reservoir is Use I-P – *water contact recreation, fishing, protection of aquatic life and wildlife and public water supply.* The applicable numeric aquatic life and human health (drinking water) criteria for dissolved Cr and Pb in freshwater are described below in Table 2 (COMAR 26.08.02.03-2G). There are two species of chromium, trivalent Cr (III) and hexavalent Cr (VI). Cr (VI) has the highest toxicity of the Cr species, therefore the numeric criteria is more stringent. Total chromium concentrations were analyzed in the water column survey and are compared with the Cr (VI) numeric water quality criterion. The Liberty Reservoir is designated a public water supply, therefore the human health (drinking water) criteria for Cr and Pb must also be achieved. The water column data presented in Section 3.1,

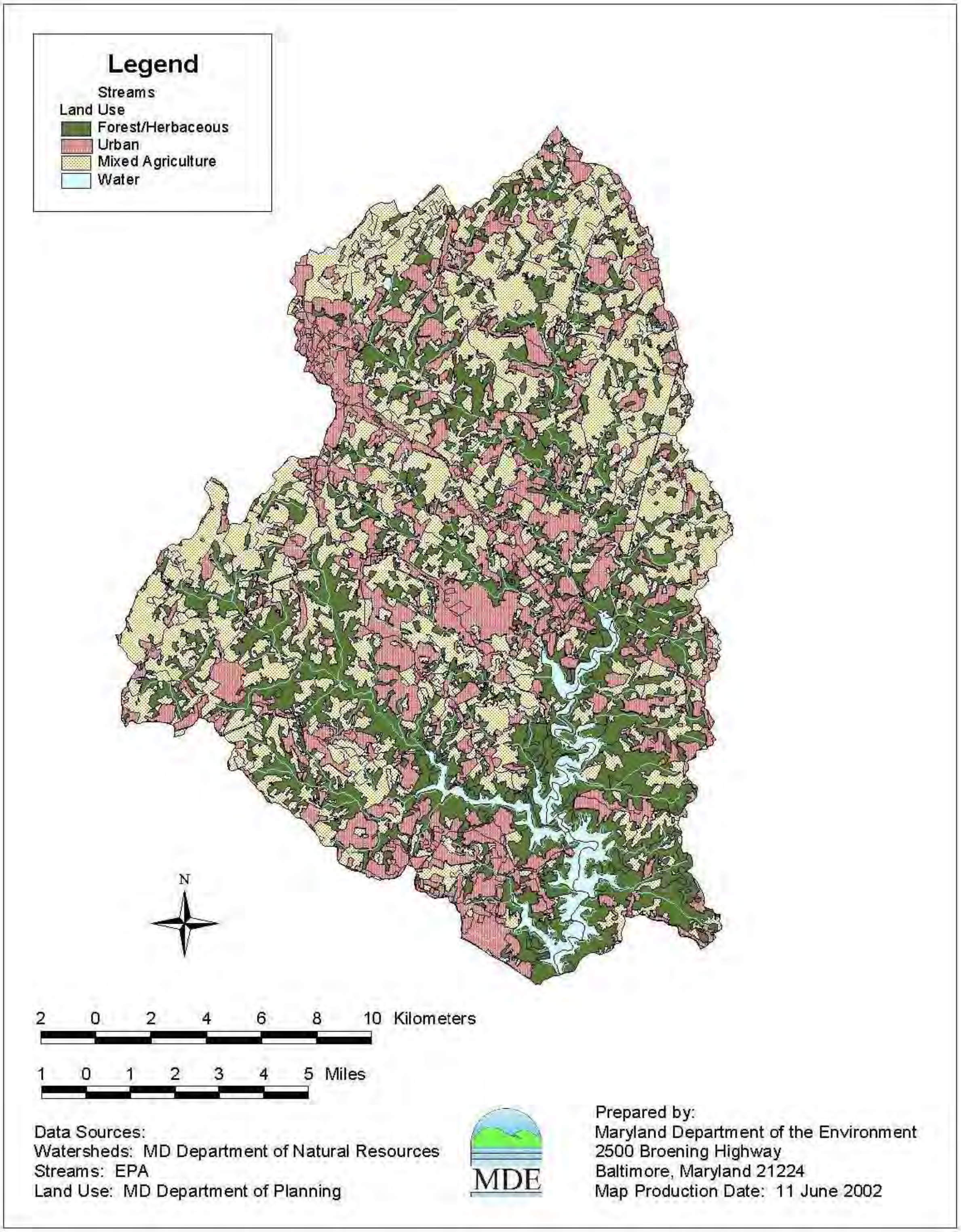

Figure 2: Land Use Map of Liberty Reservoir Watershed

Table 6 through Table 9, shows that concentrations of Cr and Pb in the water column do not exceed the aquatic life or human health (drinking water) criteria. An ambient sediment bioassay conducted in Liberty Reservoir establishes that there is no toxicity in the sediment bed of the impoundment (Fisher, 2002). Sediment chemistry analysis was not conducted because toxicity was not observed in the ambient sediment bioassay. The water column and sediment in the Liberty Reservoir impoundment are therefore not impaired by Cr or Pb, thus the designated uses are supported and the water quality standard is being met for these substances.

Table 2: Numeric Water Quality Criteria (Cr and Pb)

Metal	Fresh Water Aquatic Life Acute Criteria (µg/l)	Fresh Water Aquatic Life Chronic Criteria (µg/l)	Human Health Criteria Drinking Water (µg/l)
Cr (VI)	16	11	100 *
Pb	65	2.5	15

* Human health criterion (drinking water) is designated for Cr

Water column surveys conducted at four stations in the Liberty Reservoir from May 2001 to July 2001 were used to support the WQAs. For every sample, dissolved concentrations of Cr and Pb were determined. Sediment samples were also collected at all four monitoring stations for the sediment bioassay. Table 3 shows the list of stations with their geographical coordinates and descriptive location in the Liberty Reservoir. Refer back to Figure 1 for station locations.

Table 3: Water Quality Analysis Stations for Liberty Reservoir

Station I.D.	GPS coordinates	Station Description
LI01	39.380 76.892	Reservoir
LI02	39.408 76.883	Reservoir
LI03	39.428 76.569	Reservoir
LI04	39.469 76.887	Reservoir

Water column sampling was performed four times at each station from May 2001 to July 2001 to capture seasonal variation. The sampling dates were as follows: 5/21/01 (spring wet weather); 6/14/01 (spring dry weather); 7/26/01 (summer dry weather) and 7/30/01 (summer wet weather).

For the water quality evaluation a comparison is made between the water column concentrations of Cr and Pb and fresh water aquatic life chronic criteria, the more stringent of the numeric water quality criteria for Cr (VI) and Pb. Hardness concentrations were obtained for each station to adjust the fresh water aquatic life chronic criteria that are established at a hardness of 100 mg/l for Cr (VI) and Pb. The State used hardness adjustment to calculate fresh water aquatic life chronic criteria for Pb for which toxicity is a function of total hardness. The fresh water aquatic life chronic criterion is not adjusted for Cr (VI) because hardness either does not affect the bioavailability of this metal to aquatic life or there is significant uncertainty in the correlation between hardness and criterion. According to EPA's National Recommended Water Quality

Criteria (EPA, 2002), allowable hardness values must fall within the range of 25 - 400 mg/L. MDE uses an upper limit of 400 mg/l in calculating the hardness adjusted criteria (HAC) when the measured hardness exceeds this value. Based on technical information, EPA's Office of Research and Development does not recommend a lower limit on hardness for adjusting criteria (EPA, 2002). MDE adopts this recommendation. The HAC equation for Cr and Pb is as follows (EPA, 2002):

$$HAC = e^{(m[\ln (Hardness(mg/l))]+b)} * CF$$

Where,

HAC = Hardness Adjusted Criterion (µg/l)
m = slope
b = y intercept
CF = Conversion Factor (conversion from totals to dissolved numeric criteria)

The HAC parameters for metals are presented in Table 4.

Table 4: HAC Parameters (Fresh Water Aquatic Life Chronic Criteria)

Chemical	Slope (m)	y Intercept (b)	Conversion Factor (CF)
Pb	1.2730	-4.705	1.426 - ln(hardness)*0.146

The State will perform a scientific review of all data submitted where a water quality criterion exceedance was the result of a hardness adjustment below 50 mg/L. This review is necessary because of the scientific uncertainty existing for hardness-toxicity relationships below 50 mg/l due to:

A. Paucity of toxicity test data below 50 mg/L that was used to develop the relationship between hardness and toxicity.
B. Presence/absence of sensitive species in the waterbody of concern.
C. Existence of other environmental conditions (e.g. high Dissolved Organic Carbon (DOC)), that may mitigate the toxicity of metals due to competitive binding/complexation of metals.

In instances where hardness data is not available, the State will calculate an average of existing hardness concentrations for each station. In applying average hardness, the sampling date for which hardness data is unavailable must not fall during a storm event substantially greater than the sampling dates used to calculate the average. A major rainfall event has the potential to reduce hardness below the average. An analysis of rainfall data from the National Weather Service (NWS) precipitation gauge (0180465) at Baltimore/Washington International Airport (BWI) shows no significant variation in storm events for the sampling dates, thus the average will apply. This is the closest gauge to Liberty Reservoir and is likely to be representative of the rainfall events that occur within the watershed.

3.1 WATER COLUMN EVALUATION

A data solicitation for metals was conducted by the MDE and all readily available data from the past five years was considered in the WQA. The water column data is presented in Table 6 through Table 9 for each station and is evaluated using the fresh water aquatic life chronic HAC, the more stringent of the numeric water quality criteria for Cr and Pb (Baker, 2002). Each table displays hardness (mg/l), sample concentrations (µg/l) and fresh water aquatic life chronic HAC (µg/l) by sampling date. For example, in Table 6 for the sampling date of 7/26/01 the hardness is 27.3 mg/L, hardness adjusted criterion for Pb is 0.60 µg/l and the Pb sample concentration is 0.014 µg/l. The hardness concentrations reported in bold are for sampling dates in which hardness was not measured and an average value was applied. Detection limits for the metals analyses are displayed in Table 5.

Table 5: Metals Analysis Detection Limits

Analyte	Detection Limit (µg/l)
Cr	0.03
Pb	0.003

Table 6: Station LI01 Water Column Data

Sampling Date	5/21/01		6/14/01		7/26/01		7/30/01	
Hardness (mg/l)	29		**28.1**		27.3		**28.1**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
Cr	0.07	11	0.11	11	0.06	11	0.21	11
Pb	ND	0.64	0.007	0.61	0.014	0.60	ND	0.61

* Fresh Water Aquatic Life Chronic HAC
A) Cr (VI) criterion is applied
B) Hardness adjustment is unnecessary for Cr (VI)
ND - Not detected

Table 7: Station LI02 Water Column Data

Sampling Date	5/21/01		6/14/01		7/26/01		7/30/01	
Hardness (mg/l)	28.7		27.6		27.7		**28**	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
Cr	0.08	11	0.11	11	0.05	11	0.2	11
Pb	ND	0.63	0.005	0.63	0.013	0.61	ND	0.61

Table 8: Station LI03 Water Column Data

Sampling Date	5/21/01		6/14/01		7/26/01		7/30/01	
Hardness (mg/l)	29		28.5		27.8		28.4	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
Cr	0.1	11	0.07	11	0.03	11	0.2	11
Pb	ND	0.64	0.011	0.63	0.007	0.61	ND	0.62

* Fresh Water Aquatic Life Chronic HAC
A) Cr (VI) criterion is applied
B) Hardness adjustment is unnecessary for Cr (VI)
ND - Not detected

Table 9: Station LI04 Water Column Data

Sampling Date	5/21/01		6/14/01		7/26/01		7/30/01	
Hardness (mg/l)	32.1		30.15		30.06		30.8	
Analyte	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)	Sample (µg/l)	Criteria* (µg/l)
Cr	0.09	11	0.11	11	ND	11	0.19	11
Pb	0.041	0.72	0.031	0.67	0.025	0.67	ND	0.68

The range of concentrations for Cr and Pb sampled in the field survey are as follows:

Cr = ND to 0.21 µg/l
Pb = ND to 0.041 µg/l

Hardness ranged from 27.3 mg/l to 32.1 mg/l. The concentration ranges of Cr and Pb are well below their associated fresh water aquatic life chronic HAC. The criteria were not exceeded by any of the Cr or Pb samples.

3.2 SEDIMENT TOXICITY EVALUATION

To complete the WQA, sediment quality in the Liberty Reservoir was evaluated using 10-day survival and growth whole sediment tests with the freshwater amphipod *Hyallela azteca*. This species was chosen because of its ecological relevance to the waterbody of concern. *H. azteca* is an EPA-recommended test species for assessing the toxicity of freshwater sediments (EPA, 2000). Four surficial sediment samples were collected using a petite ponar dredge (top 2 cm) by Chesapeake Biological Laboratory (CBL) from Liberty Reservoir. The sediment stations

Table 10: Sediment Toxicity Test Results

Sample	Amphipod Survival (#)	Amphipod Weight (mg)	Average Amphipod Survival (%)	Average Amphipod Weight (mg)
Control A	9	0.159	91.3	0.172
Control B	9	0.181		
Control C	10	0.182		
Control D	10	0.183		
Control E	7	0.184		
Control F	9	0.156		
Control G	10	0.176		
Control H	9	0.157		
LI-01	10	0.274	97.5	0.244
LI-01	10	0.231		
LI-01	9	0.227		
LI-01	10	0.224		
LI-01	9	0.269		
LI-01	10	0.243		
LI-01	10	0.223		
LI-01	10	0.262		
LI-02	9	0.257	95	0.252
LI-02	10	0.252		
LI-02	10	0.307		
LI-02	9	0.258		
LI-02	9	0.24		
LI-02	9	0.23		
LI-02	10	0.221		
LI-02	10	0.252		
LI-03	10	0.244	97.5	0.241
LI-03	10	0.204		
LI-03	10	0.234		
LI-03	10	0.205		
LI-03	8	0.233		
LI-03	10	0.26		
LI-03	10	0.281		
LI-03	10	0.264		
LI-04	10	0.219	97.5	0.213
LI-04	9	0.199		
LI-04	10	0.213		
LI-04	10	0.197		
LI-04	10	0.226		
LI-04	10	0.218		
LI-04	9	0.227		
LI-04	10	0.201		

correspond to the four monitoring stations sampled in the water column surveys. Refer back to Figure 1 for station locations. Sediment toxicity test results are presented in Table 10. Ten amphipods were exposed to the sediment in each sample test. The table displays amphipod survival (#), amphipod weight (mg), average amphipod survival (%), and average amphipod weight (mg).
The test considers two performance criteria, which are survival and growth. For the test to be valid the average survival in control samples must be greater than 80% and there must be sufficient growth. Survival of amphipods in the field sediment samples was not significantly different than the 91.3 % average survival demonstrated in the control samples [$p < 0.05$]. Field sediment sample average survival results were 97.5, 97.5, 95 and 97.5 percent. No sediment samples in the Liberty Reservoir exhibited toxicity contributing to mortality. Similarly, measured growth in the field sediment samples was not significantly different than in the control samples [$p < 0.05$]. In fact, growth in all of the reservoir samples was greater than in the control sediments. The weight of amphipods at the end of the growth period observed in the field sediment samples ranged from 0.213 g to 0.252 g while the weight observed in the control sample was 0.172 g. No sediment samples exhibited toxicity contributing to a reduction in growth.

4.0 CONCLUSION

The WQA shows that water quality standards for Cr or Pb are being achieved. Water column samples collected at four monitoring stations in the Liberty Reservoir, from May 2001 to July 2001, demonstrate that numeric water quality criteria are being met. Bottom sediment samples collected at four monitoring stations, and used for bioassay toxicity tests, demonstrate no impacts on survival and growth. Barring the receipt of any contradictory data, this information provides sufficient justification to revise Maryland's 303(d) list to remove Cr and Pb as impairing substances in the Liberty Reservoir impoundment.

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APPENDIX I:

Water Quality Analysis of Mercury in Fish Tissue in Liberty Reservoir in Baltimore and Carroll Counties, Maryland

FINAL

Water Quality Analysis of Mercury in Fish Tissue in Liberty Reservoir in Baltimore and Carroll Counties, Maryland

FINAL

MARYLAND DEPARTMENT OF THE ENVIRONMENT
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Submitted to:

Watershed Protection Division
U.S. Environmental Protection Agency, Region III
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July 2013

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List of Abbreviations

ASG	Atmospheric Studies Group
BCDPW	Baltimore City Department of Public Works
BIBI	Benthic Index of Biotic Integrity
C	Celsius
CBP P5.3.2	Chesapeake Bay Program Phase 5.3.2
Cl^{-1}	Chloride
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DNR	Maryland Department of Natural Resources
E_h	Oxidation Potential
EGU	Electrical Generating Unit
ft^2	Square feet
ft^3/s	Cubic feet per second
g	Grams
g/day	Grams per day
g/yr	Grams per year
g/cm^3	Grams per centimeter cubed
EPA	US Environmental Protection Agency
FIBI	Fish Index of Biotic Integrity
HAA	Maryland Healthy Air Act
Hg	Mercury
Hg0	Uncharged, elemental mercury
Hg+1	Mercurous ion
Hg+2	Mercuric ion
Hg(OH)2	Mercuric Hydroxide
HgCl2	Mercuric Chloride
HgS	Mercury Sulfide
LMB	Largemouth Bass
MD 8-Digit	Maryland 8-Digit
MATS	Mercury and Air Toxics Standards
MDE	Maryland Department of the Environment
mg/kg	Milligrams per kilogram
mm	Millimeters
mi^2	Square miles
mol/L	Mols per liter
MS4	Municipal Separate Storm Sewer System
NEI	National Emissions Inventory
NPDES	National Pollutant Discharge Elimination System
PPRP	Power Plant Research Program
RfD	Reference Dose
S^{-2}	Sulfide
SCS	Soil Conservation Service

SHA	Maryland State Highway Administration
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant
µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter
µg/kg-day	Micrograms per kilogram per day
YOY	Young of the Year

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the US Environmental Protection Agency's (EPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is required to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met (CFR 2012a). This document, upon approval by the EPA, presents a WQA of mercury (Hg) in Liberty Reservoir [Maryland 8-Digit (MD 8-Digit) basin number 02130907] (2012 Integrated Report Assessment Unit ID: MD-02130907_Liberty_Reservoir).

The MD 8-Digit Liberty Reservoir watershed consists of:

1) The actual impoundment created behind the Liberty Dam, and
2) The nontidal tributaries within the watershed that drain to the impoundment.

The use of the term "Liberty Reservoir" throughout this report will refer to solely the impoundment created behind Liberty Dam. Use of the term "non-tidal portion of the Liberty Reservoir watershed" will refer to the non-tidal tributaries within the watershed draining to the Reservoir.

Maryland's water quality standards specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life (COMAR 2012a). The specific Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Liberty Reservoir is Use I-P (*Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply*) (COMAR 2012b,c). The Maryland Department of the Environment (MDE) has identified Liberty Reservoir on the State's 2012 Integrated Report as impaired by mercury in fish tissue (2002), sediments – sedimentation/siltation (1996), nutrients – phosphorus (1996), and metals – chromium and lead (1996). The non-tidal portion of the Liberty Reservoir watershed has been identified by MDE on the State's 2012 Integrated Report as impaired by bacteria (mainstem only; 2002) and impacts to biological communities (2004) (MDE 2012).

The WQA presented herein by MDE will address the 2002 mercury in fish tissue listing for Liberty Reservoir, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. A WQA for chromium and lead in Liberty Reservoir was approved by the EPA in 2003, and a bacteria TMDL for the nontidal portion of the watershed was approved by the EPA in 2009. TMDLs for phosphorus and sediments were submitted to EPA in 2012. In the final 2012 Integrated Report, the biological listing was addressed by the Biological Stressor Identification (BSID) analysis which more specifically identified chloride as a stressor to biological communities within the 1st- through 4th-order streams of the Liberty Reservoir watershed. As a result, in the 2012 Integrated report, the biological impairment listing was replaced with a category 5 chlorides listing.

An analysis of recent fish tissue monitoring data in Liberty Reservoir demonstrates that the "fishing" designated use of the reservoir (COMAR 2012d) is supported to allow for the consumption of fish that is protective of human health, as it relates to mercury levels in fish tissue, thus indicating that the reservoir is not impaired for mercury in fish tissue. The EPA recommended and State adopted a numeric criterion concentration for methylmercury in fish tissue of 300.0 micrograms per kilogram (µg/kg). This numeric criterion is deemed to be protective of human health relative to the consumption of fish. The conclusion that the "fishing" designated use of Liberty Reservoir is being supported is based on two composite tissue samples of trophic-level four fish (in this case, largemouth bass) taken from the Reservoir in April 2012, which indicate that the median fish tissue mercury concentration is less than MDE's numeric criterion concentration for methylmercury in fish tissue, which is deemed to be protective of human health relative to the consumption of fish.

As stated above, the analysis presented in this report supports the conclusion that a TMDL for mercury is not necessary to achieve water quality standards in Liberty Reservoir. Although Liberty Reservoir does not display signs of an impairment due to mercury in fish tissue, the State reserves the right to require future controls if evidence suggests that mercury from the reservoir is contributing to downstream water quality problems. Barring the receipt of contradictory data, this report will be used to support the revision of the 2012 Integrated Report listing for mercury in fish tissue in Liberty Reservoir from Category 5 ("waterbody is impaired, does not attain the water quality standard, and a TMDL is required") to Category 2 ("waterbody is meeting some [in this case mercury in fish tissue related] water quality standards, but with insufficient data to assess all impairments").

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the US Environmental Protection Agency's (EPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is required to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met (CFR 2012a). The most common scenarios that would eliminate the need for a TMDL are:

(1) Analysis of more recent data indicating that the impairment no longer exists (i.e., water quality standards are being met);
(2) Results of more recent and updated water quality modeling demonstrate that the segment is attaining water quality standards;
(3) Refinements to water quality standards or to the interpretation of those standards accompanied by analysis demonstrating that the standards are being met;
(4) Identification and correction of errors made in the initial listing.

Based on recent data, this document, upon approval by the EPA, presents a WQA of mercury (Hg) in Liberty Reservoir [Maryland 8-Digit (MD 8-Digit) basin number 02130907] (2012 Integrated Report Assessment Unit ID: MD-02130907_Liberty_Reservoir), which indicates that a mercury impairment no longer exists in the reservoir.

The MD 8-Digit Liberty Reservoir watershed consists of:

1) The actual impoundment created behind the Liberty Dam, and
2) The nontidal tributaries within the watershed that drain to the impoundment.

The use of the term "Liberty Reservoir" throughout this report will refer to solely the impoundment created behind Liberty Dam. Use of the term "non-tidal portion of the Liberty Reservoir watershed" will refer to the non-tidal tributaries within the watershed draining to the Reservoir.

Maryland's water quality standards specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life (COMAR 2012a). The specific Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Liberty Reservoir is Use I-P (*Water Contact Recreation, Protection of Nontidal Warm Water Aquatic Life and Public Water Supply*) (COMAR 2012b,c). The Maryland Department of the Environment (MDE) has identified Liberty Reservoir on the State's 2012 Integrated Report as impaired by mercury in fish tissue (2002), sediments – sedimentation/siltation (1996), nutrients – phosphorus (1996) and metals – chromium and lead (1996). The non-tidal portion of the Liberty Reservoir watershed has been identified by MDE on the State's 2012 Integrated Report as impaired by bacteria (mainstem only; 2002) and impacts to biological communities (2004) (MDE 2012).

The WQA presented herein by MDE will address the 2002 mercury in fish tissue listing for Liberty Reservoir, for which a data solicitation was conducted, and all readily available data from the past five years have been considered. A WQA for chromium and lead in Liberty Reservoir was approved by the EPA in 2003, and a bacteria TMDL for the nontidal portion of the watershed was approved by the EPA in 2009. TMDLs for phosphorus and sediments are currently under development and are scheduled for submittal to EPA in 2012. In the final 2012 Integrated Report, the listing for impacts to biological communities within the 1st- through 4th-order streams of the nontidal portion of the Liberty Reservoir watershed includes the results of a stressor identification analysis.

MDE had previously developed a TMDL to address the 2002 Integrated Report mercury in fish tissue impairment listing for Liberty Reservoir. The *Total Maximum Daily Load of Mercury for Liberty Reservoir Baltimore and Carroll Counties, Maryland* was submitted by MDE to EPA in 2002 (MDE 2002a). Approval of the TMDL was withheld by EPA until the air deposition model, applied within the analysis to estimate the atmospheric deposition of mercury to the reservoir and its surrounding watershed, could be improved to provide more detail in terms of source assessment and deposition rates, in order to bolster the TMDL's assurance of implementation. Advances in modeling atmospheric mercury transport now enable atmospherically deposited mercury loads to be attributed to specific emission sources, both in Maryland and other states, as well as those originating from global/background sources, including natural sources. However, the analysis of fish tissue samples collected in April of 2012 in Liberty Reservoir indicate that the reservoir is no longer impaired by mercury in fish tissue. Therefore, a TMDL is not required.

This report provides an analysis of recent fish tissue monitoring data that supports the removal of the mercury in fish tissue impairment listing for Liberty Reservoir, when MDE proposes the revision of the State's Integrated Report. The remainder of this report lays out the general setting of the Liberty Reservoir watershed, presents a discussion of the reservoir's water quality characteristics relative to established water quality standards related to mercury and the applicable designated uses of the reservoir, and provides conclusions with regard to the characterization.

2.0 GENERAL SETTING

Location

The Liberty Reservoir watershed is located within the Patapsco River sub-basin of the Chesapeake Bay watershed, within Maryland. The reservoir's watershed drains 104,800 acres of western Baltimore County and eastern Carroll County (see Figure 1) (majority of watershed is located in Carroll County). A dam was completed on the North Branch Patapsco River in 1953, creating the Liberty Reservoir, which is owned by the City of Baltimore and managed by the Baltimore City Department of Public Works (BCDPW). Water supply intakes in the reservoir feed the BCDPW's Ashburton Water Filtration Plant, which provides drinking water to Baltimore City, Carroll County, and Baltimore County. The reservoir is primarily fed by the North Branch Patapsco River; other tributaries include Beaver Run, Keyer's Run, Prugh Run, Morgan Run, Middle Run, Locust Run, and Cooks Branch. There are several "high quality," or Tier II, stream segments (Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) aquatic life assessment scores > 4 (scale 1-5)) located within the watershed requiring the implementation of Maryland's anti-degradation policy (COMAR 2012e). These include Keyser Run, Cooks Branch, an unnamed tributary to Morgan Run, an unnamed tributary to Little Morgan Run, and portions of Morgan Run, Joe Branch, Little Morgan Run, Middle Run, Beaver Run, the North Branch Patapsco River mainstem, and an unnamed tributary to the North Branch Patapsco River mainstem (MDE 2011a). Approximately 1.9% percent of the watershed area is covered by water (i.e., streams, ponds, etc). The total population in the MD 8-digit Liberty Reservoir watershed is approximately 115,288 (US Census Bureau 2010).

Reservoir Characteristics

Table 1 lists the Liberty Reservoir's physical characteristics.

Table 1: Current Physical Characteristics of Liberty Reservoir[1]

Location:	Baltimore and Carroll Counties, Maryland
Latitude - At Dam:	39° 22' 36" N
Longitude - At Dam:	76° 53' 30" W
Surface Area:	3,106 acres (107.3×10^6 ft^2)[2]
Normal Reservoir Depth:	133 feet
Designated Use:	I-P (Water Supply/Recreation) (COMAR 2012b)
Average Volume:	132,000 acre-feet
Drainage Area to Reservoir:	164 mi^2 (104,800 acres)[3]
Average Discharge:[4]	20 ft^3/s

Notes: [1] Sources: Weisberg et al. 1985 and James, Saffer, and Tallman 2001.
[2] ft^2: square feet.
[3] mi^2: square miles.
[4] ft^3/s: feet cubed per second.

Geology/Soils

The Liberty Reservoir watershed lies within the north-central Piedmont Plateau physiographic province of Maryland, which is characterized by a gentle to steep rolling topography. The surficial geology of the watershed is composed of hard, crystalline igneous and metamorphic rocks of probable volcanic origin, which consist mainly of schist and gneiss, with smaller amounts of marble (Edwards 1981). The watershed drains in a northwest to southeasterly direction, following the dip of the underlying crystalline bedrock in the Piedmont physiographic province. Ground water is found primarily in the fractures and bedding-plane partings of rocks, but it may also be found in the solutional cavities of limestone and marble deposits (McCoy and Summers 1992).

The soils in the Liberty Reservoir watershed belong primarily to the Baile soil series (59%) and the Chester soil series (40%) (USDA 2013). The Baile soil series consists of soils that are very deep and poorly drained. These soils can be found on upland depressions and foot slopes and were formed in mica schist and granitized schist and gneiss. The Chester soil series consists of deep, well drained soils that are located on upland divides and upper slopes and were formed in materials weathered from micaceous schist (USDA 1976).

Soil type for the Liberty Reservoir watershed is also characterized by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) into four hydrologic soil groups: Group A soils have high infiltration rates and are typically deep well drained/excessively drained sands or gravels; Group B soils have moderate infiltration rates and consist of moderately deep-to-deep and moderately well-to-well drained soils, with moderately fine/coarse textures; Group C soils have slow infiltration rates with a layer that impedes downward water movement, and they primarily have moderately fine-to-fine textures; Group D soils have very slow infiltration rates consisting of clay soils with a permanently high water table that are often shallow over nearly impervious material. The Liberty Reservoir watershed is comprised primarily of Group B soils (81%) with smaller portions of Group C and Group D soils (13% and 6% respectively) (USDA 2013).

Land-Use

Based on the Chesapeake Bay Program Phase 5.3.2 (CBP P5.3.2) watershed model 2009 Progress Scenario, the land-use distribution in the watershed is 35.3% forested, 31.0% urban, 1.9% water, and 31.8% agricultural. The land-use distribution is displayed and summarized in Figures 2 and 3.

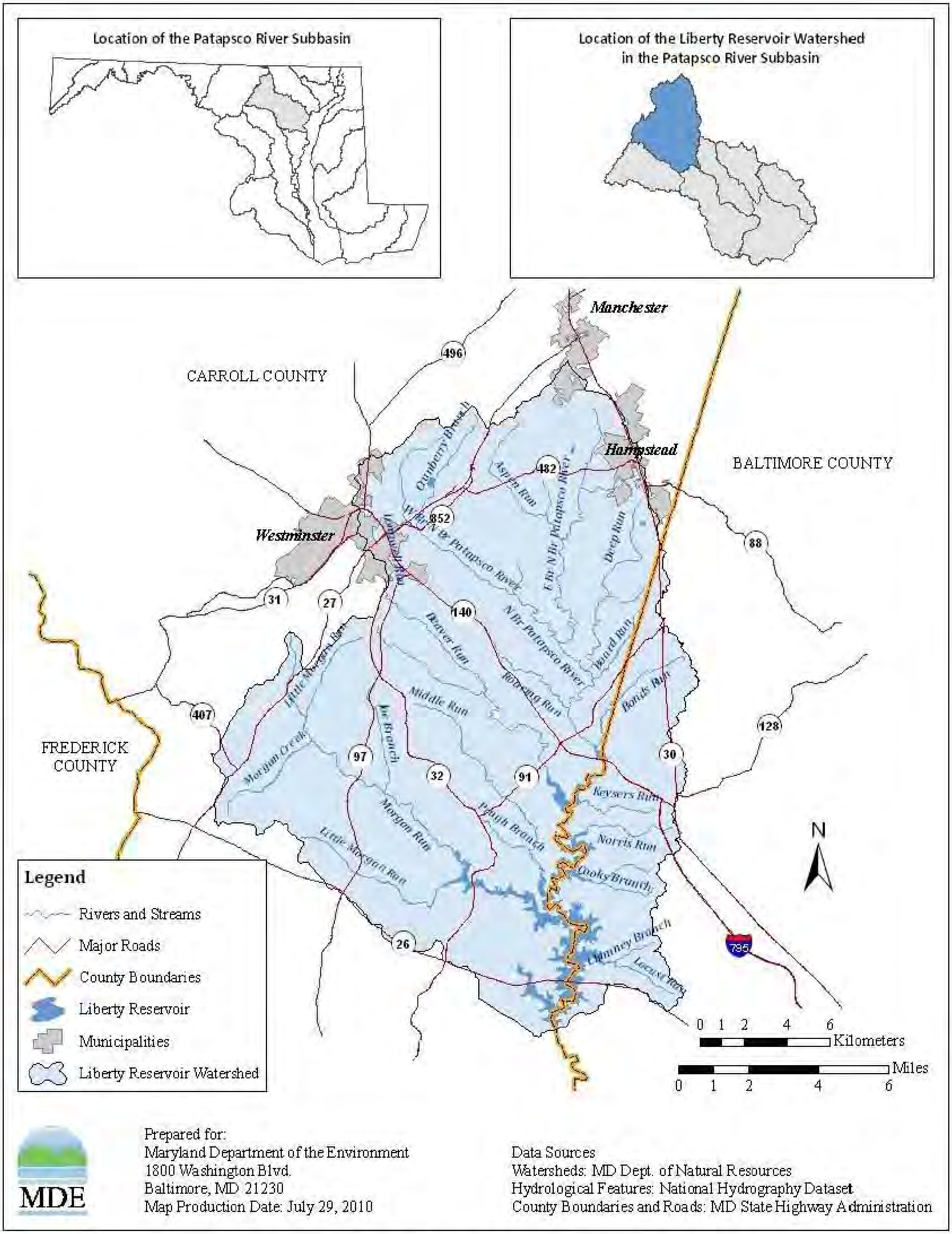

Figure 1: Location Map of the Liberty Reservoir Watershed

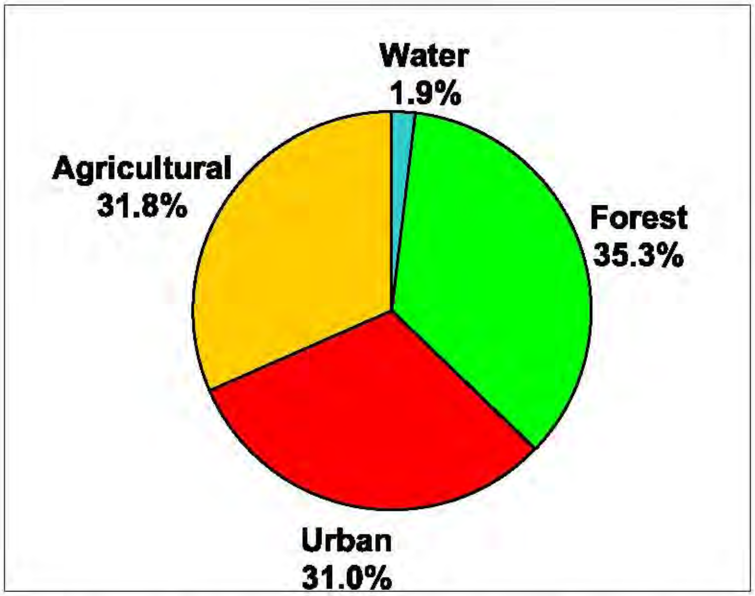

Figure 2: Land-Use Distribution in the Liberty Reservoir Watershed

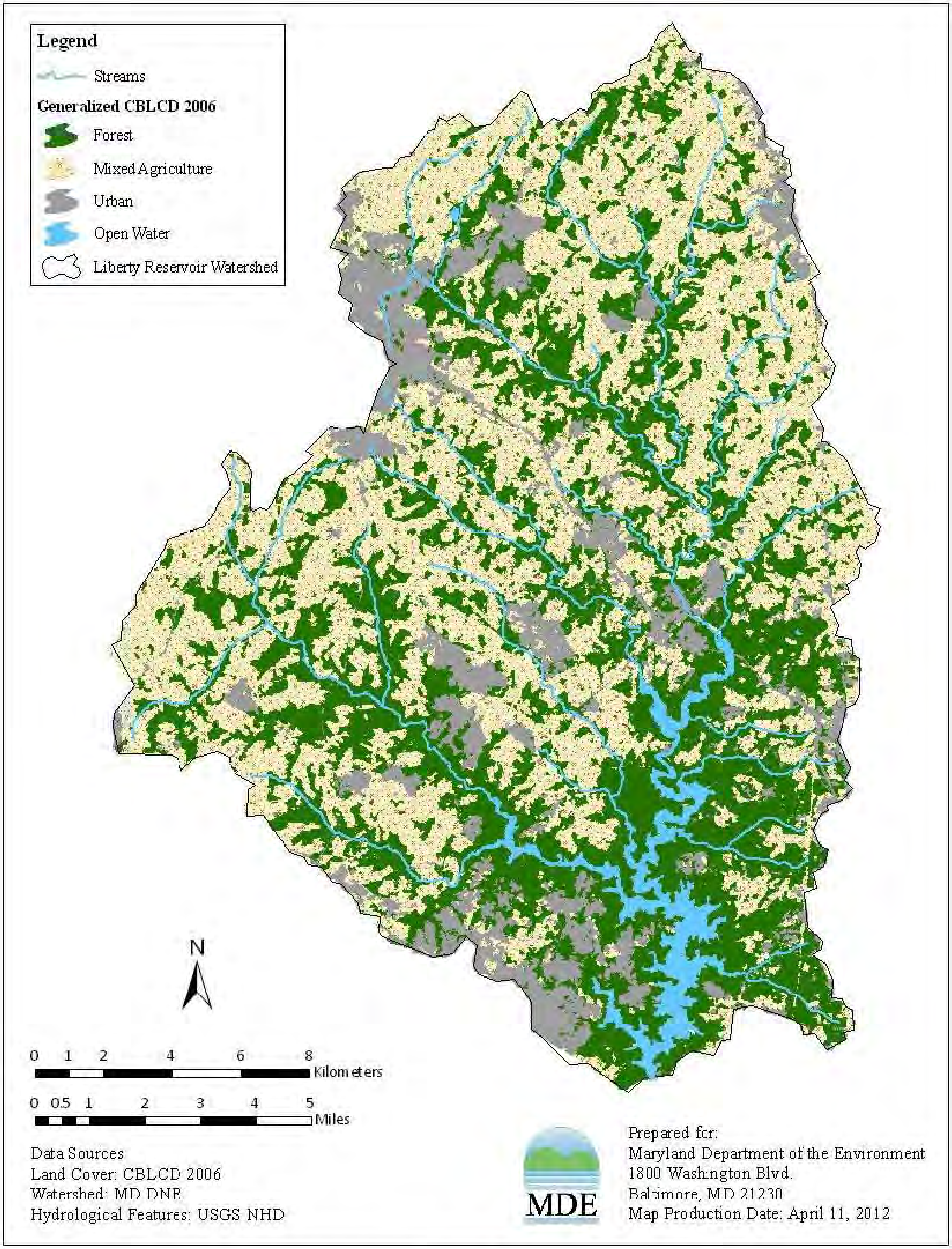

Figure 3: Land-Use Map for the Liberty Reservoir Watershed

3.0 WATER QUALITY CHARACTERIZATION

A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life, primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Maryland's water quality standards specify that all surface waters of the State shall be protected for water contact recreation, fishing, and the protection of aquatic life (COMAR 2012a). The specific Maryland Surface Water Use Designation in COMAR for Liberty Reservoir is Use I-P (*Water Contact Recreation, Protection of Nontidal Warm Water Aquatic Life and Public Water Supply*) (COMAR 2012b,c).

MDE interprets the "fishable" designated use under section 101(a) of the CWA to mean the protection of human health, as it relates to the consumption of fish and shellfish. Thus, "fishable" implies that when fish and shellfish are harvested, they can be safely consumed by humans (COMAR 2010d). The 2012 Integrated Report states that the Liberty Reservoir does not support its "fishing" designated use, due to elevated mercury levels in fish tissue, which does not allow for the consumption of fish that is protective of human health.

Mercury chemistry in the environment is complex and not fully understood. Mercury exhibits the properties of a metal, specifically its persistence in the environment, and it does not chemically break down beyond its elemental, uncharged form (Hg^0) or its ionic mercurous (Hg^+) and mercuric (Hg^{+2}) forms. However, it also has properties similar to a hydrophobic organic chemical, due to its ability to methylate via a bacterial process. Methylation of mercury can occur in water, sediment, and soil matrices under anaerobic conditions and, to a lesser extent, under aerobic conditions. In water, methylation occurs mainly at the water-sediment interface and at the oxic-anoxic boundary within the water column. Methylmercury is readily taken up by organisms and subsequently bioaccumulates, as it has a strong affinity for muscle tissue. It is effectively transferred through the food web, with tissue concentrations magnifying at each trophic-level. This process can result in elevated levels of methylmercury in organisms high on the food chain, despite nearly immeasurable mercury/methylmercury concentrations in the water column. Appendix B discusses mercury chemistry, including methylation, in greater detail.

In fish tissue, mercury is not usually found in concentrations high enough to cause fish to exhibit signs of toxicity, but the mercury in sport (trophic-level four) fish can present a potential health risk to humans. The health risk to humans posed by the mercury content in consumed fish tissue is due to methylmercury. Typically, almost all of the mercury found in fish tissue (90 to 95%) is in the form of methylmercury.

For public health purposes, MDE has the responsibility to monitor and evaluate the contaminant levels in Maryland's fish, shellfish and crabs, to determine if contaminant levels are within the limits established as safe for human consumption. In fulfillment of this public health responsibility, MDE issued a statewide fish consumption advisory for mercury in fish in 2001. This original 2001 advisory was established statewide as a precautionary measure, because the primary source of mercury is understood to be atmospheric deposition, which is widely dispersed (MDE 2001). This advisory has subsequently been revised, and is updated on a regular basis, using actual monitoring data of fish tissue mercury concentrations. The updated advisory provides guidelines on fish consumption (allowable meals per month) for recreational anglers and their families (not including commercially harvested fish) and includes fish species in publicly accessible lakes, impoundments, rivers, etc. (MDE 2011b). The fish consumption guidelines were developed, in part, to protect against the possible neurobehavioral damages that could occur during human fetal development and early childhood.

To determine if the "fishing" designated use of a waterbody is impaired for a particular contaminant, the contaminant fish tissue concentration from a composite sample of fish fillets of any single common species of recreational fish is compared to the criterion concentration or established fish consumption advisory threshold concentration (for contaminants that do not have an existing criterion as per Maryland's water quality standards) for that contaminant. Appendix C describes in further detail MDE's methodology for fish tissue sampling and subsequent assessment of impairment relative to the "fishing" designated use of waterbodies throughout the state. Maryland collects composite samples of trophic-level four fish, such as largemouth bass, of legally harvestable size on a regular basis to determine whether or not the fish are safe for human consumption. If the numeric criterion or fish consumption advisory threshold concentration for a given contaminant is exceeded, the waterbody's "fishable", or "fishing", designated use is not being attained, and the waterbody is considered to be impaired for the presence of that contaminant in fish tissue.

As a state water quality standard (i.e., numeric criterion for a specific designated use), MDE has adopted the EPA recommended concentration of 300 micrograms per kilogram (µg/kg) as the mercury (methyl, not total) fish tissue concentration considered to be the highest possible concentration, or threshold concentration, that still supports the "fishable" designated use of a waterbody (US EPA 2001; COMAR 2012f). This numeric criterion represents the maximum allowable methylmercury concentration in the tissues of both freshwater and estuarine fish, as it relates to the protection of human health due to fish consumption amongst the general population. A waterbody with mercury fish tissue concentrations greater than 300 µg/kg is therefore not in attainment of its "fishing" designated use and is thus impaired for mercury in fish tissue.

Both the fish consumption guidelines and numeric criterion were developed based on methylmercury concentrations; however, the analysis presented in this document, and in general, MDE's analysis of fish tissue monitoring data and resultant fish consumption advisories, are conducted using total mercury. Therefore, they incorporate a conservative assumption.

Based on fish tissue data collected in 2000 and 2002, Maryland identified the Liberty Reservoir as impaired due to elevated levels of mercury in fish tissue on the 2002 Integrated Report (MDE 2002b). The 2002 Liberty Reservoir mercury TMDL (see Introduction for details) was based on the fish tissue sampling data collected in 2000 and 2002. The geometric mean methylmercury concentration for the sixteen fish tissue samples was 261 µg/kg. In 2002, the State's Integrated Report impairment listing threshold for methylmercury in fish tissue was a geometric mean of 235 µg/kg. In 2004, MDE adopted a 300 µg/kg arithmetic mean methylmercury in fish tissue concentration as a new threshold for identifying waters impaired for mercury in fish tissue (MDE 2004). Then, in 2010, MDE changed the assessment methodology yet again so as to calculate the median, total mercury concentration in fish tissue for comparison to the 300 μg/kg threshold concentration. The change to a 300 μg/kg concentration made MDE's Integrated Report impairment listing threshold consistent with the State adopted, numeric criterion (i.e., water quality standard), as recommended by EPA, for mercury in fish tissue. The new impairment listing threshold was based on findings from a statewide survey of fish consumption by licensed recreational fishermen.

Subsequent fish tissue sampling in the reservoir was performed in 2003, 2007 and 2010. These samples will not be included in this WQA, however, since they do not meet MDE's data requirements (See Appendix C for further details on data requirements). The samples from 2003 and 2007 are not considered to be representative of current water quality conditions in the reservoir (i.e., they are considered to be out-dated). Three of five fish tissue composite samples collected in 2010 were not included in this analysis since the sampled fish species, blue gill (two samples) and yellow perch (one sample), are not uniquely trophic-level four consumers. The two other composite samples collected in 2010 were from largemouth bass, but they will not be included in this analysis because the average length of the sampled bass was 246 millimeters (mm), or about 10.7 inches, which is below the legal, "keepable", length of 12 inches. Therefore, these fish tissue samples would not be representative of mercury concentrations in consumable fish in the reservoir (See Appendix D for further details).

Scientists have linked methylmercury concentrations in fish tissue with atmospheric mercury deposition, and it is estimated that two-thirds of this atmospheric deposition is derived from anthropogenic sources (Hammerschmidt and Fitzgerald 2006). Furthermore, EPA considers coal-fired electric power generating plants to be the largest anthropogenic source of mercury emissions in the nation. Thus, while a portion of the total mercury loading to Liberty Reservoir may be transported by National Pollutant Discharge Elimination System (NPDES) regulated urban stormwater conveyance systems, it can be assumed that the origin of any urban stormwater mercury loadings is from atmospheric deposition, since there are very few land sources of mercury. The same rationale also applies to both non-NPDES regulated urban stormwater mercury loadings and other nonpoint watershed mercury loadings. Whatever small contribution of mercury loadings that is derived from on-land sources can be attributed to the improper management of mercury-containing products.

The contribution of mercury to the reservoir from NPDES process water point sources is assumed to be minimal, as well. In 2008, MDE sampled the effluent of a large number of municipal wastewater treatment plants (WWTPs) in Maryland to determine the representative mercury concentrations in municipal WWTP discharges. This analysis was specifically conducted to aid in the development of mercury TMDLs in Maryland. Based on this study, in the majority of watersheds in Maryland, the total mercury contribution from process water point source loads is be considered insignificant (MDE 2010). Therefore, all NPDES regulated sources are considered to be insignificant contributors of mercury to the Liberty Reservoir. For informational purposes, Appendix A presents a summary of discharge permits in the watershed.

3.1 WATER QUALITY EVALUATION

A data solicitation for information pertaining to the mercury in fish tissue impairment in Liberty Reservoir, as identified in the 2010 Integrated Report, was conducted by MDE in 2012, and all readily available data from the past five years has been considered.

3.1.1 FISH TISSUE ANALYSIS

For this WQA, fish tissue concentrations of total mercury – instead of methylmercury – will be compared to the 300 µg/kg numeric criterion.

Two, five-fish composite samples of trophic-level four fish – largemouth bass – were collected from Liberty Reservoir and analyzed for total mercury fish tissue concentrations. The physical characteristics of the fish that were collected (see Appendix D) confirm that all of the fish were of legal, "keepable" size (*i.e.*, greater than 12 inches long). By only including fish that were larger than 12 inches in length, the median fish tissue mercury concentration of the sampling data is indicative of long-term mercury accumulation in fish that are several years old. Thus, the fish tissue sampling data reflects any and all seasonal variations and critical conditions in water quality that have occurred over the life of the fish in the reservoir. The results of this analysis are shown below in Table 2.

Table 2: Summary of Fish Tissue Mercury Concentrations in Liberty Reservoir

Species	Trophic Level	Composite Sample Count	Number of Fish per Composite	Total Mercury Median Concentration (µg/kg)	MDE Human Health Criterion for Mercury in Fish Tissue (µg/kg)
Largemouth Bass	4	1	5	269.7	300
Largemouth Bass	4	2	5	128.9	300

The median mercury concentration in the composite fish tissue samples is 199.3 µg/kg. Thus, MDE's 300 µg/kg fish tissue mercury concentration, numeric criterion for the protection of human health via fish consumption is not being exceeded in Liberty Reservoir. Therefore, based on this fish tissue sampling data, the "fishable" designated use of the Liberty Reservoir is not impaired due to mercury in fish tissue.

3.1.2 ATMOSPHERIC DEPOSITION MODELING

As discussed previously in Section 3.0, the atmospheric deposition of mercury has been identified as the only significant source of mercury to the Liberty Reservoir watershed. Therefore, it is the primary source of mercury found in the tissues of the reservoir's fish populations. Most of this atmospherically deposited mercury is believed to have originated from stationary combustion sources, and of the mercury loading to the reservoir watershed from these stationary combustion sources, a large portion comes from electric generating units (EGUs). The Maryland Healthy Air Act (HAA) was put into effect in July of 2007 and was expected to reduce mercury loadings to watersheds throughout the State by requiring EGUs covered under the act to reduce their mercury emissions. An 80% reduction in mercury emissions, from 2002 levels, was required from these EGUs by 2010, and a 90% reduction, from 2002 levels, was required by 2013 (COMAR 2012g).

To estimate the effectiveness of the HAA, the atmospheric deposition of mercury to several MD 8-Digit watersheds was modeled for two different years: the baseline year, 2007, before implementation of the HAA; and 2013, when the HAA caps will be fully implemented. The estimates were performed using the California PUFF Model, an advanced, non-steady-state, time variable, Gaussian meteorological and air quality model, approved by EPA for many atmospheric pollutant modeling purposes. The model scenario runs and output were made available to MDE via the Maryland Department of Natural Resources' (DNR's) Power Plant Research Program (PPRP). Sherwell et al. (2006) provides a detailed description of the CALPUFF model, and the model itself is made available to the general public for download by the Atmospheric Studies Group (ASG) (ASG 2012).

The sources of the mercury loadings in the model were divided into five categories: EGUs and non-EGUs, both within and outside of Maryland; and global background (including natural) sources of mercury. Appendix E presents a discussion of the assumptions used in developing the model. The model output for the Liberty Reservoir watershed is summarized in Table 3 below.

Table 3: Modeled Atmospheric Mercury Loads to the Liberty Reservoir Watershed Using CALPUFF

Source Category	Baseline (2007)		Full HAA Implementation (2013)	
	Load (g/yr)[1]	Percent of Total (%)	Load (g/yr)	Percent of Total (%)
Maryland Non-EGU Total	508.5	5.4	508.5	6.6
Maryland EGU Total	1,927.0	20.4	176.2	2.3
Non-Maryland Non-EGU	1,577.3	16.7	1,577.3	20.5
Non-Maryland EGU	2,993.9	31.7	2,993.9	38.9
Global Background	2,431.7	25.8	2,431.7	31.6
TOTAL	**9,438.0**	**100**	**7,688.0**	**100**

Note: [1] g/yr: grams per year.

The model shows a large decrease (19.0%) in total mercury loadings to the reservoir watershed from 2007 to 2013. This entire reduction in loadings is due to reductions in mercury emissions from Maryland EGUs, as required by the HAA, and the subsequent decrease in atmospherically deposited mercury to the reservoir's watershed from these EGUs (90.9%). Because the HAA mandated EGUs reduce mercury emissions 80% by 2010, significant decreases in mercury emissions have already been achieved. It follows that the deposition of mercury to various watersheds across the State should have decreased as well. Thus, the decrease in fish tissue mercury concentrations that was observed between 2002 and 2012 is consistent with the decrease in mercury emissions and corresponding deposition to the watershed during the HAA implementation period. However, there is a lag-time between: (a) the reduction of mercury emissions, (b) the reduction of mercury loadings to the reservoir watershed, and (c) the corresponding uptake, bioaccumulation, and biomagnification of mercury through the food web in the reservoir. Therefore, the full benefits of the HAA may continue to become apparent as time progresses. Further reductions to mercury loadings, particularly due to a reduction in mercury emissions from non-Maryland EGUs, could occur with the eventual implementation of the federal Mercury and Air Toxics Standards (MATS) (U.S. EPA 2012).

4.0 CONCLUSION

Based on the analysis presented in this report, it is concluded that the State water quality standards (*i.e.*, numeric criterion) for mercury in fish tissue are being met within the Liberty Reservoir. Thus, the "fishing" designated use of the reservoir, which allows for the consumption of fish that is protective of human health, is being supported. This conclusion is based on two composite fish tissue samples collected from Liberty Reservoir in April 2012. The composite samples had a median mercury concentration (199.3 μg/kg) that was substantially less than MDE's numeric criterion for the protection of human health via fish consumption (300 μg/kg). Therefore, it is concluded that the impoundment is not impaired for mercury in fish tissue.

MDE maintains the authority to re-list the Liberty Reservoir as impaired for mercury in fish tissue in the future if new data indicate that the "fishing" designated use of the reservoir is no longer being met. Monitoring of the reservoir will continue through MDE's Fish and Shellfish Monitoring Program. This program will sample fish tissue from the Liberty Reservoir at least once every five years to determine whether various species of fish are safe for human consumption. If the results of this sampling indicate that fish from the reservoir are unsafe to eat because of mercury concentrations in their tissue, the reservoir would be re-listed as impaired for mercury in fish tissue on the Integrated Report.

Also, beginning in 2008, MDE in conjunction with DNR began commissioning yearly "young-of-the-year" (YOY) fish surveys. For the State's freshwater impoundments, largemouth bass were selected as the indicator species. Since the fish sampled in this study are yearlings and have therefore only had half a year of exposure to methylmercury, they are not representative of consumable fish and could not be used as data for a new listing. They should, however, show medium- and long-term mercury trends in fish tissue far sooner than would adult fish. Therefore, this sampling should be useful in determining the effectiveness of state and federal programs, such as the HAA and MATS, in reducing the atmospheric deposition of mercury. However, because YOY sampling began in 2008, at this point, there is not sufficient data to support any meaningful conclusions.

Barring the receipt of contradictory data, this report will be used to support the revision of the Integrated Report listing for mercury in fish tissue for Liberty Reservoir from Category 5 ("waterbody is impaired, does not attain the water quality standards, and a TMDL is required") to Category 2 ("waterbody is meeting some [in this case mercury in fish tissue related] water quality standards, but with insufficient data to assess all impairments") when MDE proposes the revision of Maryland's Integrated Report.

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APPENDIX A – MDE Permit Information

Table A-1: Liberty Reservoir Watershed Process Water Point Source Permit Information

NPDES #	Facility Name	Permit Type	
MD0067644	CRANBERRY WATER TREATMENT PLANT	MUNICIPAL	INDIVIDUAL
MD0067652	FREEDOM DISTRICT WATER TREATMENT PLANT	MUNICIPAL	INDIVIDUAL
MD0001384	CONGOLEUM CORPORATION	INDUSTRIAL	INDIVIDUAL
MD0001881	BTR HAMPSTEAD, LLC	INDUSTRIAL	INDIVIDUAL
MD0058556	CITY OF WESTMINSTER KOONTZ WELL	INDUSTRIAL	INDIVIDUAL
MDG492472	S & G CONCRETE - FINKSBURG PLANT	INDUSTRIAL	GENERAL
MDG766057	CARROLL COUNTY FAMILY YMCA[1]	INDUSTRIAL	GENERAL
MDG766199	THE BOSTON INN, INC.[1]	INDUSTRIAL	GENERAL
MDG766199	GLYNDON TRACE CONDOMINIUMS[1]	INDUSTRIAL	GENERAL
MDG766210	FOUR SEASONS SPORTS COMPLEX[1]	INDUSTRIAL	GENERAL
MDG766371	FREEDOM SWIM CLUB[1]	INDUSTRIAL	GENERAL
MDG766379	GREEN VALLEY SWIM CLUB[1]	INDUSTRIAL	GENERAL
MDG766048	MCDANIEL COLLEGE[1]	INDUSTRIAL	GENERAL
MDG675043	MARYLAND MILITARY FACILITY – CAMP FRETTERD[2]	INDUSTRIAL	GENERAL
MDG675029	PEARLSTONE FAMILY CAMP[2]	INDUSTRIAL	GENERAL

Notes: [1] Swimming pool discharge permits.
[2] Hydrostatic testing facility discharge permits.

Table A-2: Liberty Reservoir Watershed NPDES Stormwater Permit Information

NPDES Permit #[1,2,3]	Facility Name[4]	NPDES Regulated Stormwater Permit Type[2,3]
MD0068314	BALTIMORE COUNTY MS4	BALTIMORE COUNTY PHASE I MS4
MD0068331	CARROLL COUNTY MS4	CARROLL COUNTY PHASE I MS4
MD0055501	STATE HIGHWAY ADMINISTRATION MS4 (PHASE I)	SHA PHASE I MS4
MDR05550	CITY OF WESTMINSTER MS4	MUNICIPAL PHASE II MS4
MDR05550	CITY OF HAMPSTEAD MS4	MUNICIPAL PHASE II MS4
MDR05550	CITY OF MANCHESTER MS4	MUNICIPAL PHASE II MS4
N/A - 02SW1965	BALTIMORE COUNTY BUREAU OF HIGHWAYS - SHOP 3	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1219	BFI WASTE SERVICES, LLC - FINKSBURG	OTHER NPDES REGULATED STORMWATER
N/A - 02SW3001	BULLOCK'S MEATS, INC.	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1824	C AND C MULCH PROCESSING, LLC	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1755	CARROLL COUNTY REGIONAL AIRPORT	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1452	CONDON'S AUTO PARTS, INC.	OTHER NPDES REGULATED STORMWATER
N/A - 02SW2006	GENERAL DYNAMICS ROBOTIC SYSTEMS	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0664	HODGES LANDFILL	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0954	JONES AUTO & SALVAGE	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1144	M & M TRUCK & EQUIPMENT CO., INC.	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0660	NORTHERN MUNICIPAL LANDFILL	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1345	SHA - WESTMINSTER SHOP	OTHER NPDES REGULATED STORMWATER
N/A - 02SW1908	SMITH BROTHERS AUTO PARTS	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0078	THOMAS, BENNETT & HUNTER, INC. - SHOP FACILITY	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0794	TOBACCO TECHNOLOGY, INC.	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0115	CJ MILLER. LLC	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0719	MARYLAND PAVING - FINKSBURG	OTHER NPDES REGULATED STORMWATER
N/A - 02SW0029	MARANDA INDUSTRIES	OTHER NPDES REGULATED STORMWATER
N/A	MDE GENERAL PERMIT TO CONSTRUCT	OTHER NPDES REGULATED STORMWATER

Notes: [1] N/A: Permit does not have an NPDES number. For the industrial stormwater permits, the permit number listed is the MDE permit application number.

[2] Although not listed in this table, some individual permits from Table A-1 incorporate stormwater requirements, and there are additional, general, permitted Phase II MS4s, such as military bases, hospitals, etc., within the watershed.

[3] MS4: Municipal Separate Storm Sewer System

[4] SHA: State Highway Administration

APPENDIX B – Mercury Chemistry

Mercury is a Group IIB (Periodic Table) element, as are zinc and cadmium. Elemental metallic mercury exists as a high luster silver-colored liquid at room temperature. Some key physical properties of metallic mercury are listed in Table B-1. Varied industrial and consumer uses of mercury include electrical apparatuses, such as fluorescent light tubes, and control instruments - including thermometers and barometers. It is also used in the manufacture of pharmaceuticals, antifouling paints, mercury fulminate, electrolytic cells, and dental amalgams. Mercury is also a constituent of a number of antiseptics such as *mercurochrome, merthiolate and mercressin.*

Mercury and all its compounds are toxic. Mercury fulminate, $Hg(CNO)_2$, is used as a detonator for initiating the explosion of smokeless powder and various high explosives (i.e., TNT, dynamite, etc.). Mercury fulminate is very unstable and can be exploded by shock; its explosion causes the main explosive to be detonated. Mercury electrolytic cells are used in a manufacturing process for chlorine/alkali production. Liquid mercury dissolves many metals, especially the softer ones such as copper, silver, gold, and the alkali elements. The resulting alloys, which may be solids or liquids, are called amalgams. Dental amalgam is an alloy of mercury and silver.

Table B-1: Physical Properties of Metallic Mercury[1]

Atomic Number	80
Atomic Weight	200.59
Density[2,3]	13.5 g/cm^3 @ 25°C
Melting Point	-39°C
Boiling Point	357°C
Water Solubility (molarity)[4]	3.0 x 10^{-7} (mol/L) @25°C
Water Solubility (mass basis)[5]	60 µg/L @ 25°C

Notes: [1] Source: (Dean 1992)
[2] g/cm^3 = grams per centimeters cubed
[3] C = Celcius
[4] Mol/L = mols per liter
[5] µg/L = micrograms per liter

Mercury chemistry in the environment is complex and not fully understood. Mercury exhibits the properties of a metal, specifically its persistence in the environment, and it does not chemically break down beyond its elemental, uncharged form or its ionic forms. Mercury exists in three oxidation states: the metallic, uncharged (elemental) state (Hg^0); the mercurous (ionic) state (Hg^{+1}); and the mercuric (ionic) state (Hg^{+2}). These states are separated by only a small oxidation potential (E_h), and the metal readily participates in redox chemical reactions. In particular, Hg^{+1} salts disproportionate under many conditions to yield the Hg^{+2} salt and metallic mercury. Reduction of both the mercurous and the mercuric salts normally yields the metal state (PPRP 1994).

Mercury in natural waters may appear in the form of any of its three oxidation states. The predominate state is determined by the hydrogen ion concentration (described as pH) and the reduction potential of the water. Since chloride and sulfide complex Hg^{+1} and Hg^{+2} ions, concentrations of these compounds also affect the relative species distribution (Gilmour and

Henry 1991; Shimomura 1989). Ammonium, carbonate, bicarbonate, and phosphate concentrations do not affect speciation (PPRP 1994).

In natural systems, pH is generally in the range of 5 to 8 and the reduction potential is typically less than 0.5 Volts. For these systems, mercury sulfide (HgS) and metallic mercury are the most likely solids to be found in equilibrium with saturated solutions of mercury salts at moderate chloride (Cl^{-1}) and sulfide (S^{-2}) concentrations. The predominant species in the corresponding solutions will be mercuric hydroxide ($Hg(OH)_2$) and mercuric chloride ($HgCl_2$) in well oxygenated waters and Hg metal in poorly oxygenated waters (Gavis and Ferguson 1972). In reducing sediments, HgS will predominate the solid phase (PPRP 1994).

Mercury also has properties similar to a hydrophobic organic chemical due to its ability to be methylated through a bacterial process. Methylation of mercury can occur in water, sediment, and soil matrices under anaerobic conditions, and to a lesser extent, under aerobic conditions. In water, methylation occurs mainly at the water-sediment interface and at the oxic-anoxic boundary within the water column. Methylated mercury is thought to be thermodynamically unstable in water; thus, organic mercury found in surface waters is probably preserved through reaction barriers that prevent degradation.

Methylation does not occur in the presence of moderate to high sulfide concentrations, which immobilize Hg^{+2} ions (PPRP 1994). In fish tissue, mercury is not usually found in concentrations high enough to cause fish to exhibit signs of toxicity, but the mercury in sport (trophic-level four) fish can present a potential health risk to humans. This health risk to humans posed by the mercury content in fish tissue, if consumed, is due to methylmercury. Typically, almost all of the mercury found in fish tissue (90 to 95%) is in the form of methylmercury.

Methylmercury is readily taken up by organisms and subsequently bioaccumulates, as it has a high affinity for muscle tissue. It is effectively transferred through the food web, with tissue concentrations magnifying at each trophic-level. This process can result in elevated levels of methylmercury in organisms high on the food chain, despite nearly immeasurable mercury/methylmercury concentrations in the water column.

APPENDIX C – Integrated Report Methodology for Determining Toxic Impairments to the "Fishing" Designated Use of Waterbodies in Maryland

Fish Tissue

Section 101(a)(2) of the CWA established as a national goal the attainment of "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water." This is commonly referred to as the "fishable/swimmable" goal of the Act. Additionally, Section 303(c)(2)(A) of the CWA requires water quality standards to protect public health and welfare, enhance the quality of water, and serve the purposes of the Act. The EPA, along with MDE, interprets these regulations to mean that not only should waters of the State support thriving and diverse fish and shellfish populations, but they should also support fish and shellfish which, when caught, are safe to consume by humans.

Some of the toxic contaminants that are present in various waterbodies throughout Maryland tend to bioaccumulate (primarily mercury and PCBs) in the tissues of gamefish (e.g., largemouth bass) and bottom-feeders (e.g. catfish), often at elevated levels. When the concentration levels of any one specific contaminant in fish tissue are elevated to such a degree that it increases the risk of chronic health effects in humans, if consumed regularly, the State has the responsibility to issue a fish consumption advisory for that particular contaminant in the specific species of fish, in which the contaminant concentrations were found to be elevated. Fish consumption advisories are designed to protect the general public as well as sensitive populations (i.e., young children and women who are or may become pregnant). In addition to such advisories, which stop at four meals per month, the Department also provides fish consumption recommendations, which stop at 8 meals per month. These additional recommendations are issued in order to protect the more frequent fish consumers.

When a fish consumption advisory (not a recommendation) is issued for a waterbody, the designated use of that waterbody (i.e., the "fishing" designated use) is <u>usually</u> not being supported. This <u>may</u> result in the identification of a waterbody as impaired on the Integrated Report for the specific contaminant that is found at elevated levels in fish tissue. To determine if a waterbody is impaired, the median contaminant concentration in the edible portion of the common recreational fish species is compared to the established fish consumption advisory threshold or numeric criterion concentration, when applicable. If the threshold/criterion concentration is exceeded, the waterbody's designated use is not being met, and the waterbody is identified as impaired. The existing fish tissue numeric criteria are used as the impairment identification thresholds (i.e., determines if the "fishing" designated use is supported), where applicable (e.g., the methylmercury numeric fish tissue criterion is 300 µg/kg). For contaminants that do not have an existing criterion (e.g., PCBs), MDE has defined "fishable" as the ability to consume <u>at least</u> four meals per month (i.e., the threshold number of allowable meals per month for a fish consumption advisory) of common recreational fish species by an individual that has a mass of 76 kilograms (kg) (see Contaminant Thresholds Section below).

Data Requirements

The data requirements for identifying a waterbody as impaired are very similar to the data requirements for issuing a fish consumption advisory, with only slight variations. The data requirements for identifying a waterbody as impaired are as follows:

1. All available data should be reviewed when making decisions regarding waterbody impairments.
2. Only contaminant concentrations that are measured in the part of the fish or shellfish that are typically consumed will be used for assessment purposes. Maryland publishes fish consumption advisories based on contaminant concentrations found in fillets only; therefore, only data collected from fillets are to be considered when making decisions regarding waterbody impairments. For shellfish, only data collected from the soft tissue portions of the organisms will be considered.
3. The fish tissue data needs to be collected from the specific waterbody in question.
4. The size of the fish sampled should be within the legal slot limit. If no slot limit exists for a specific species, best professional judgment for a minimum size of a given species will be applied.
5. Minimum data requirement: five fish (individual or composite of the same resident species) for a given waterbody. At times, in order to protect more sensitive populations, MDE might issue a fish consumption advisory that is based on an incomplete dataset (less than five fish of the same species). However, the publication of such an advisory does not automatically result in the identification of a waterbody as impaired. Thus, the minimum data requirement needs to be met in order to identify a waterbody as impaired.
6. All fish that comprise a composite sample must be within the same size class (i.e., the smallest fish must be within seventy-five percent of the total length of the largest fish).
7. Species used to determine impairment should be representative of the waterbody. Migratory and transient species may be used if they are the dominant recreational species, but they should only be used in conjunction with resident species, especially in the case of the tidal rivers of the Chesapeake Bay.
8. To ensure that the impairment is temporally relevant, impairments based on the minimum required samples should be re-sampled prior to TMDL development.

Contaminant Thresholds

The contaminant threshold and criterion concentrations are based on a risk assessment calculation that incorporates numerous risk parameters such as contaminant concentration, reference dose/cancer slope factor, exposure duration, lifetime span, and for some contaminants, cooking loss.

Table C-1: Threshold/Criterion Concentrations for Toxic Contaminants of Concern

Contaminant	Threshold/Criterion	Basis	Group
Mercury	300 µg/kg – wet weight	EPA/MDE Human Health Fish Tissue Consumption Criteria	General Public[1]
PCBs	39.0 µg/kg – wet weight	4 meals/month concentration level	General Public[1]

Note: [1] General Public: Individual with a mass of 76 kg.

Over time, advances in science may require changes in risk assessment parameters that may increase or decrease the currently used contaminant thresholds/criterion, and consequently the concentrations used to make decisions regarding impairments. If this occurs, waterbodies that were previously identified as impaired may no longer be considered impaired, or new waterbodies may need to be identified as impaired.

APPENDIX D – Composite Fish Tissue Sampling Data and Analysis

This appendix presents all of the fish tissue sampling data applied in the analysis.

Table D-1: Liberty Reservoir Composite Fish Tissue Sampling Data

Sample ID	Trophic-Level	Species[1]	Collection Date	Composite #	Length (mm)	Weight (g)[2]	Total Mercury Tissue Concentration (µg/kg)
04_2012_LIBE_01	4	LMB	4/9/12	1	400	935	-
04_2012_LIBE_02	4	LMB	4/9/12	1	426	1,066	-
04_2012_LIBE_03	4	LMB	4/9/12	1	374	802	-
04_2012_LIBE_04	4	LMB	4/9/12	1	370	651	-
04_2012_LIBE_08	4	LMB	4/9/12	1	353	546	-
Composite #1[4]					**385**	**800**	**269.7**
04_2012_LIBE_05	4	LMB	4/9/12	2	348	539	-
04_2012_LIBE_06	4	LMB	4/9/12	2	332	491	-
04_2012_LIBE_07	4	LMB	4/9/12	2	337	516	-
04_2012_LIBE_09	4	LMB	4/9/12	2	314	410	-
04_2012_LIBE_10	4	LMB	4/9/12	2	310	367	-
Composite #2 [4]					**328**	**465**	**128.9**
MEDIAN [5]					**356**	**632**	**199.3**

Notes: 1 LMB = Largemouth Bass
[2] g = grams
[4] Composite length and weight are averages from the individual fillets.
[5] The total length, weight, and mercury tissue concentration are medians of the two composites.

An analysis of the length and weight of these fish indicates that they were of legal, "keepable" size.

APPENDIX E– Mercury Air Deposition

Mercury air deposition loads to the Liberty Reservoir watershed representative of several different scenarios were estimated using the CALPUFF model, which is an advanced, non-steady-state Gaussian meteorological and air quality model that has been approved by EPA for many atmospheric pollutant modeling purposes. The CALPUFF model scenario runs and output were made available to MDE via Maryland DNR's PPRP. The scenarios were conducted and analyzed in the following manner (Sherwell et al. 2006):

- Baseline loads were calculated based on the 2007 stack test for sources in Maryland and the 2002 National Emissions Inventory (NEI) for other sources (NEI 2012). This calculation was representative of typical conditions over the last decade, assuming no reductions from Maryland's HAA;
- Loads reflecting reduced emissions resulting from full implementation of the HAA in 2013 as specified in COMAR were calculated (COMAR 2012g);
- Analysis to separate loads originating from the following sources were performed:
    - Within the state of Maryland:
        - EGUs vs. non-EGUs;
    - Outside of Maryland, but within the model domain (roughly the eastern third of the United States):
        - EGUs vs. non-EGUs;
    - Global background loads, including natural loads (Sherwell et al. 2006).

APPENDIX J:

Watershed Report for Biological Impairment of Liberty Reservoir Watershed in Baltimore and Carroll Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation

Watershed Report for Biological Impairment of the Liberty Reservoir Watershed in Baltimore and Carroll Counties, Maryland
Biological Stressor Identification Analysis Results and Interpretation

FINAL

DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard, Suite 540
Baltimore, Maryland 21230-1718

Submitted to:

Water Protection Division
U.S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

January 2012

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List of Abbreviations

AR	Attributable Risk
BIBI	Benthic Index of Biotic Integrity
BSID	Biological Stressor Identification
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
DNR	Maryland Department of Natural Resources
FIBI	Fish Index of Biologic Integrity
IBI	Index of Biotic Integrity
MDDNR	Maryland Department of Natural Resources
MDE	Maryland Department of the Environment
MBSS	Maryland Biological Stream Survey
mg/L	Milligrams per liter
µeq/L	Micro equivalent per liter
µS/cm	Micro Siemens per centimeter
MS4	Municipal Separate Storm Sewer System
n	Number
NPDES	National Pollution Discharge Elimination System
PSU	Primary Sampling Unit
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment

Executive Summary

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met.

The Liberty Reservoir watershed (basin code 02130907), located in Baltimore and Carroll Counties, was identified on the Integrated Report under Category 5 as impaired by chromium (Cr), lead (Pb), nutrients, suspended sediments (1996 listings), methylmercury (2002 listing), and fecal coliform and evidence of biological impacts (2004 listings) (MDE 2010). The Cr, Pb, nutrients, suspended sediment and methylmercury impairments were listed for the impoundment, and the fecal coliform and biological impairments were listed for the non-tidal streams. The 1996 nutrients listing was refined in the 2008 Report and phosphorus was identified as the specific impairing substance in the impoundment. Similarly, the 1996 suspended sediment listing was refined in the 2008 Integrated Report to a listing for total suspended solids in the impoundment. The Cr and Pb impairments in the impoundment were delisted by way of a WQA submitted to the USEPA in 2003. A TMDL for methylmercury in fish tissue in the impoundment was submitted to the USEPA in 2002. A TMDL for fecal coliform, for the non-tidal streams, to address the 2002 bacteria listing was submitted to the USEPA in 2008.

In 2002, the State began listing biological impairments on the Integrated Report. The current MDE biological assessment methodology assesses and lists only at the Maryland 8-digit watershed scale, which maintains consistency with how other listings on the Integrated Report are made, how TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds with multiple impacted sites by measuring the percentage of stream miles that have an Index of Biotic Integrity (IBI) score less than 3, and calculating whether this is significantly different from a reference condition watershed (i.e., healthy stream, <10% stream miles degraded).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for Liberty Reservoir and all tributaries upstream have been designated as Use I-P – *water contact recreation, protection of aquatic life, and public water supply.* Middle Run from the headwaters to the confluence with Prugh Branch, and an unnamed tributary of Little Morgan have been designated as Use I - *water contact recreation and* *protection of warmwater aquatic life.* Roaring Run has been designated as Use III – *nontidal cold water*. Beaver Run, Cooks Branch, East Branch Patapsco River, Keysers Run, Locust Run, Morgan Run, Norris Run, Snowdens Run and all their tributaries have been designated as Use III-P – *nontidal cold water and public water supply*. The mainstem of the North and West Branches of the Patapsco River above Liberty Reservoir, and Cranberry Branch and its tributaries have been designated as Use IV-P – *recreational trout waters and public water supply* (COMAR 2009 a, b, c, d, e). The Liberty Reservoir watershed is not attaining its designated use of protection of aquatic life because of biological impairments. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine the predominant cause of reduced biological conditions, thus enabling the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the biological community, and the likely impact these stressors would have on the degraded sites in the watershed.

The BSID analysis uses data available from the statewide MDDNR MBSS. Once the BSID analysis is completed, a number of stressors (pollutants) may be identified as probable or unlikely causes of poor biological conditions within the Maryland 8-digit watershed study. BSID analysis results can be used as guidance to refine biological impairment listings in the Integrated Report by specifying the probable stressors and sources linked to biological degradation.

This Liberty Reservoir watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and which may be reviewed in more detail in the report entitled "Maryland Biological Stressor Identification Process" (MDE 2010). Data suggest that the degradation of biological communities in the Liberty Reservoir watershed is strongly influenced by urban land use and its concomitant effects: altered hydrology and elevated levels of nutrients, inorganic pollutants and conductivity (a measure of the presence of dissolved substances). The urban development of landscapes creates broad and interrelated forms of degradation (i.e., hydrological, morphological, and water chemistry) that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between highly urbanized and agricultural landscapes and degradation in the aquatic health of non-tidal stream ecosystems.

The results of the BSID process, and the probable causes and sources of the biological impairments in the Liberty Reservoir watershed can be summarized as follows:

- The BSID process has determined that the biological communities in the Liberty Reservoir watershed are likely degraded due to inorganic pollutants (i.e., chlorides). Chloride levels are significantly associated with degraded biological conditions and found in approximately 55% of the stream miles with poor to very poor biological conditions in the Liberty Reservoir watershed. Impervious surfaces and urban runoff cause an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed. The BSID results thus support Category 5 listing of chloride for the watershed.

- There is presently a Category 5 listing for phosphorus (impoundment) in Maryland's 2010 Integrated Report; BSID analysis identified TN, not phosphorus, as a potential water chemistry stressor in the Liberty Reservoir watershed. The presence of TN in the Liberty Reservoir watershed shows a possible association (33% of stream miles) with degraded biological conditions. Because nitrogen generally exists in quantities greater than necessary to sustain algal growth, excess nitrogen per se is not the cause of the biological impairment in the Liberty Reservoir watershed. MDE considers phosphorus to be the limiting nutrient species in an ecosystem, and since phosphorus was not identified as a potential stressor, reduction of nitrogen loads would not be an effective means of ensuring that the watershed is free from impacts on aquatic life from eutrophication.

1.0 Introduction

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met. In 2002, the State began listing biological impairments on the Integrated Report. Maryland Department of the Environment (MDE) has developed a biological assessment methodology to support the determination of proper category placement for 8-digit watershed listings.

The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological condition to Integrated Report categories. In the data quality review step, available relevant data are reviewed to ensure they meet the biological listing methodology criteria of the Integrated Report (MDE 2010). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or blackwater streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, <10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors responsible for biological impairments was limited to the round two Maryland Biological Stream Survey (MBSS) dataset (2000–2004) because it provides a broad spectrum of paired data variables (i.e., biological monitoring and stressor information) to best enable a complete stressor analysis. The BSID analysis then links potential causes/stressors with general causal scenarios and concludes with a review for ecological plausibility by State scientists. Once the BSID analysis is completed, one or several stressors (pollutants) may be identified as probable or unlikely causes of the poor biological conditions within the Maryland 8-digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

The remainder of this report provides a characterization of the Liberty Reservoir watershed, and presents the results and conclusions of a BSID analysis of the watershed.

2.0 Liberty Reservoir Watershed Characterization

2.1 Location

The Liberty Reservoir watershed is located within Baltimore (17%) and Carroll (83%) Counties, Maryland. The North Branch Patapsco River is the main tributary flowing into the watershed; the stream system then empties into the Maryland 8-Digit Lower Patapsco River watershed (see Figure 1). The river's west branch begins north of Westminster and the east branch begins south of Manchester. Flowing south, the river becomes Liberty Reservoir, a 3,100-acre drinking water supply (and recreational impoundment) for Carroll and Baltimore Counties, and Baltimore City. The major tributaries include Beaver Run, Morgan Run, Middle Run, and Little Morgan Run. The drainage area of the Maryland 8-digit watershed Liberty Reservoir is 101,400 acres. The watershed is located the Eastern Piedmont region, one of three distinct eco-regions identified in the MDDNR MBSS Index of Biological Integrity (IBI) metrics (Southerland et al. 2005a) (see Figure 2).

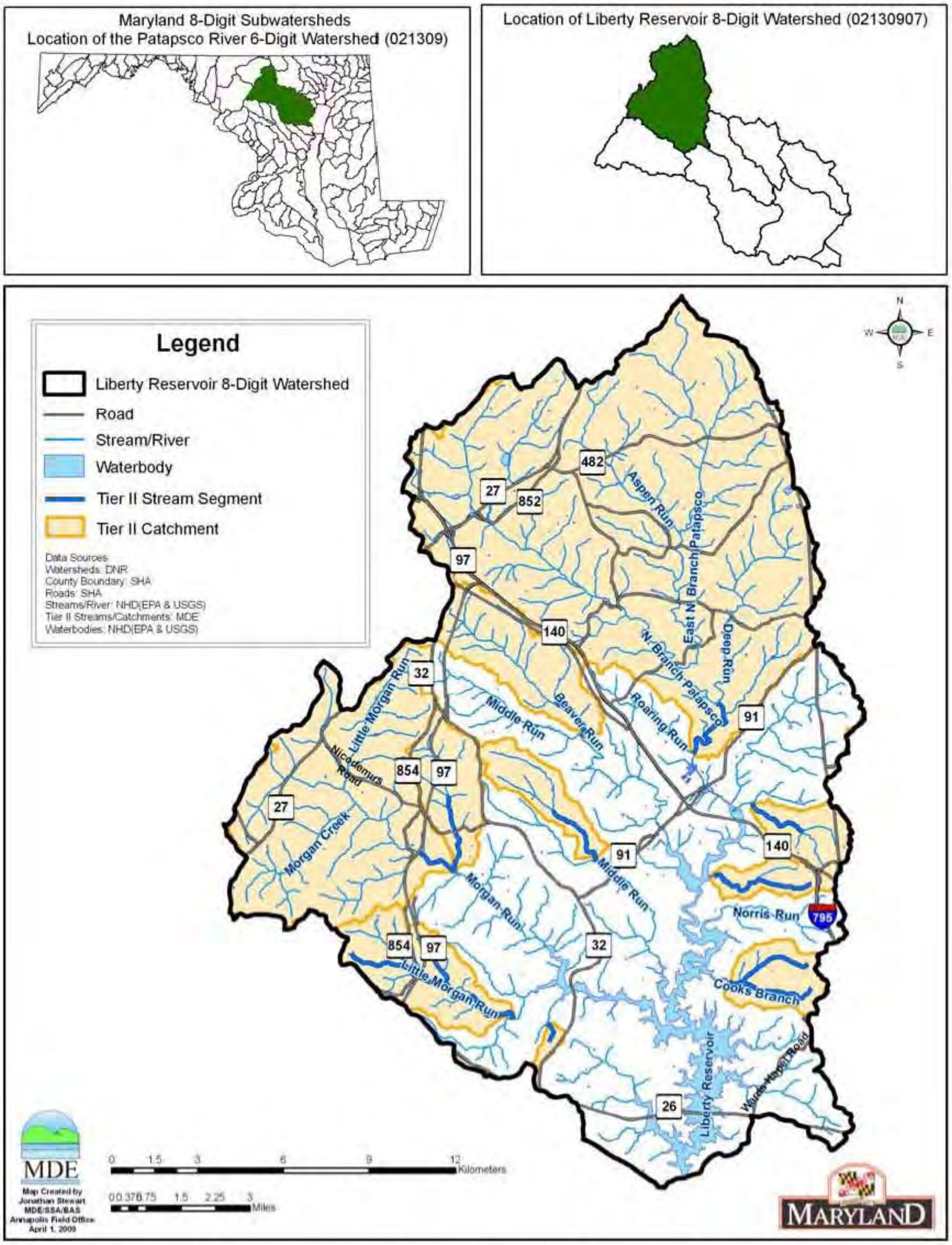

Figure 1. Location Map of the Liberty Reservoir Watershed

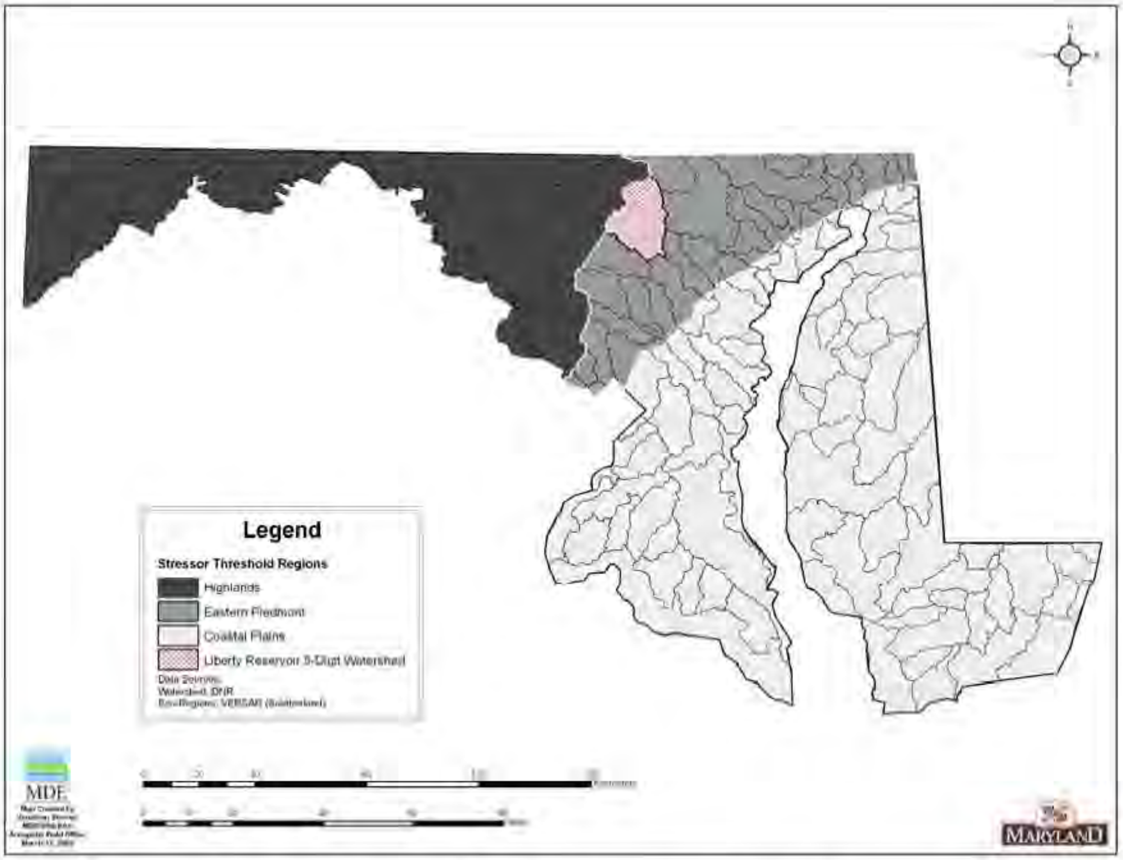

Figure 2. Eco-Region Map of the Liberty Reservoir Watershed

2.2 Land Use

The Liberty Reservoir watershed lies entirely in the Piedmont Plateau Physiographic Province. This province is characterized by gentle to steep rolling topography, low hills, and ridges. The Liberty Reservoir watershed contains primarily agricultural land use, specifically cropland and livestock/feeding operations (see Figure 3). There are three large urban areas within the watershed including Hampstead, Manchester, and Westminster, and two smaller urban areas, Eldersburg, Finksburg, and Reisterstown. Interstate 795 and other State and county paved roads (i.e., Routes 26, 27, 32, 97, and 140) connect urban areas within the region. Maryland Routes 26 and 140 cross over the Liberty Reservoir impoundment. Forests are located primarily around Liberty Reservoir, maintained by the City of Baltimore to protect the quality of the drinking water, and along Morgan Run tributary. Two Natural Environmental Areas (NEAs) are located within the watershed, Morgan Run NEA and Soldier's Delight NEA southeast of the impoundment. The land use distribution in the watershed is approximately 39% agriculture/pasture, 31% forest/herbaceous, 27% urban, and 3% water (see Figure 4)

(MDP 2002). Urban impervious surface is 3% of the total land use in the watershed (USEPA 2008).

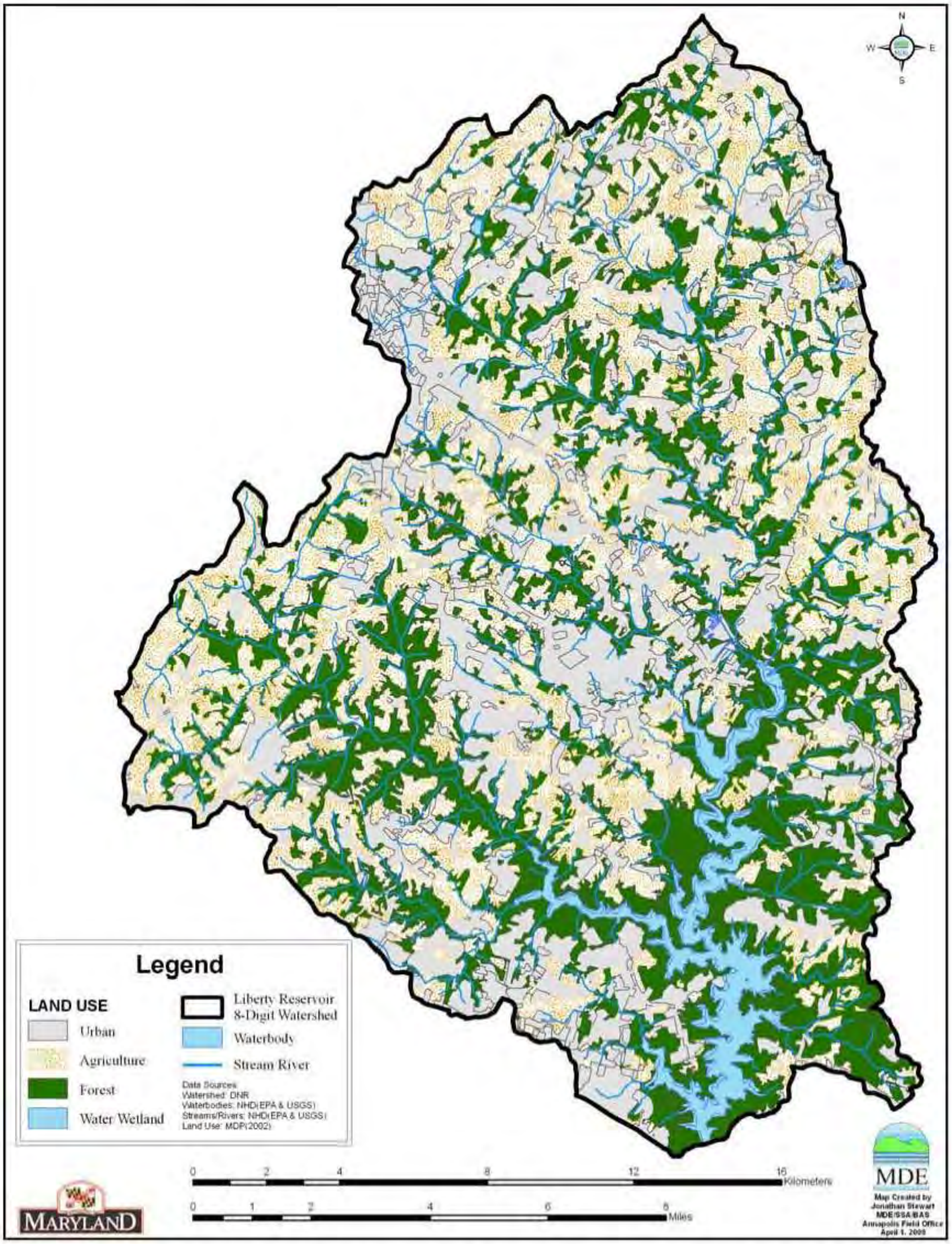

Figure 3. Land Use Map of the Liberty Reservoir Watershed

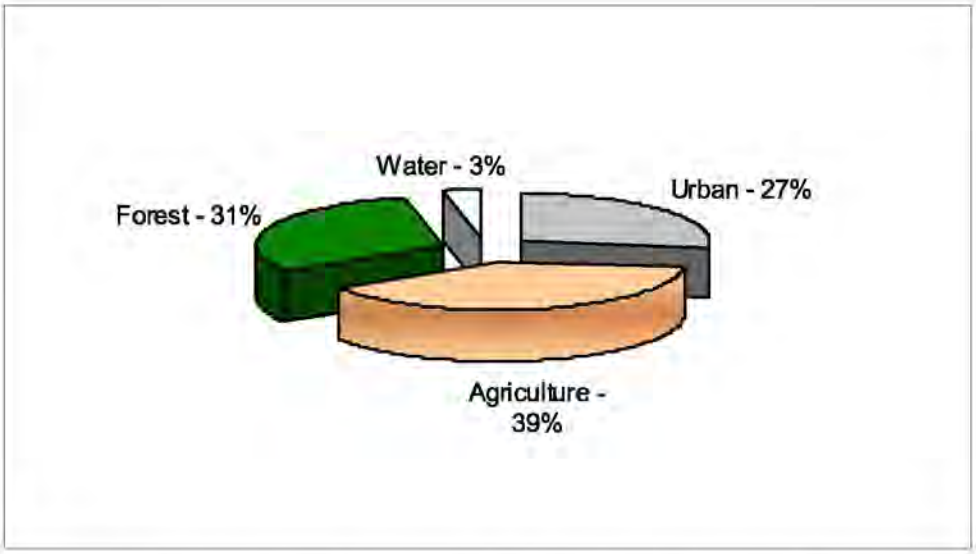

Figure 4. Proportions of Land Use in the Liberty Reservoir Watershed

2.3 Soils/hydrology

The Liberty Reservoir watershed lies within the north central Piedmont Plateau Physiographic Province and is characterized by gentle to steep rolling topography, low hills and ridges. Hard, crystalline igneous and metamorphic rocks of volcanic origin consisting primarily of schist and gneiss characterize the surficial geology of the watershed (Edwards 1981). The watershed drains in a northwest to southeast direction, following the dip of the underlying crystalline bedrock in the province. The surface elevations range from approximately 980 feet to 420 feet at the Liberty Reservoir Spillway. Stream channels of the sub-watersheds are well incised in the Eastern Piedmont, and exhibit relatively straight reaches and sharp bends, reflecting their tendency to following zones of fractured or weathered rock (CES 1995).

3.0 Liberty Reservoir Water Quality Characterization

3.1 Integrated Report Impairment Listings

The Maryland Department of the Environment has identified the waters of Liberty Reservoir on the State's Integrated Report under Category 5 as impaired by chromium (Cr), lead (Pb), nutrients, suspended sediments (1996 listings), methylmercury (2002 listing), and fecal coliform and evidence of biological impacts (2004 listings). The Cr, Pb, nutrients, suspended sediment and methylmercury impairments were listed for the impoundment, and the fecal coliform and biological impairments were listed for the non-tidal streams. The 1996 nutrients listing was refined in the 2008 Integrated Report and phosphorus was identified as the specific impairing substance in the impoundment. Similarly, the 1996 suspended sediment listing was refined in the 2008 Integrated Report to a listing for total suspended solids in the impoundment. The Cr and Pb impairments in the impoundment were delisted by way of a WQA submitted to the USEPA in 2003. A TMDL for methylmercury in fish tissue in the impoundment was submitted to the USEPA in 2002. A TMDL for fecal coliform, for the non-tidal streams, to address the 2002 bacteria listing was submitted to the USEPA in 2008.

3.2 Impacts to Biological Communities

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Liberty Reservoir watershed and all tributaries upstream have been designated as Use I-P – *water contact recreation, protection of aquatic life, and public water supply*. Middle Run from the headwaters to the confluence with Prugh Branch, and an unnamed tributary of Little Morgan have been designated as Use I - *water contact recreation and protection of warmwater aquatic life*. Roaring Run has been designated as Use III – *nontidal cold water*. Beaver Run, Cooks Branch, East Branch Patapsco River, Keysers Run, Locust Run, Morgan Run, Norris Run, Snowdens Run and all their tributaries have been designated as Use III-P – *nontidal cold water and public water supply*. The mainstem of the North and West Branches of the Patapsco River above Liberty Reservoir, and Cranberry Branch and its tributaries have been designated as Use IV-P – *recreational trout waters and public water supply* (COMAR 2009 a, b, c, d, e). Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Liberty Reservoir watershed is designated as a Tier II (i.e., Maryland's antidegradation policy) waterbody; this Tier II designation protects surface water that is better than the minimum requirements specified by water quality standards. Liberty Reservoir watershed's Tier II catchments are Cooks Branch, Beaver Run, Joe Branch, Keysers Run, Little Morgan, Middle Run, Morgan Run, North Branch Patapsco, and the North Branch Patapsco UT (COMAR 2009f).

The Liberty Reservoir watershed is listed under Category 5 of the 2010 Integrated Report as impaired for impacts to biological communities. Approximately 22% of stream miles in the Liberty Reservoir watershed are estimated as having fish and/or benthic indices of biological impairment in the poor to very poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include seventy-four stations. Fourteen of the seventy-four have degraded benthic and/or fish index of biotic integrity (BIBI, FIBI) scores significantly lower than 3.0 (i.e., very poor to poor). The principal dataset, i.e. MBSS Round 2, contains thirty-eight sites; with ten having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Liberty Reservoir watershed.

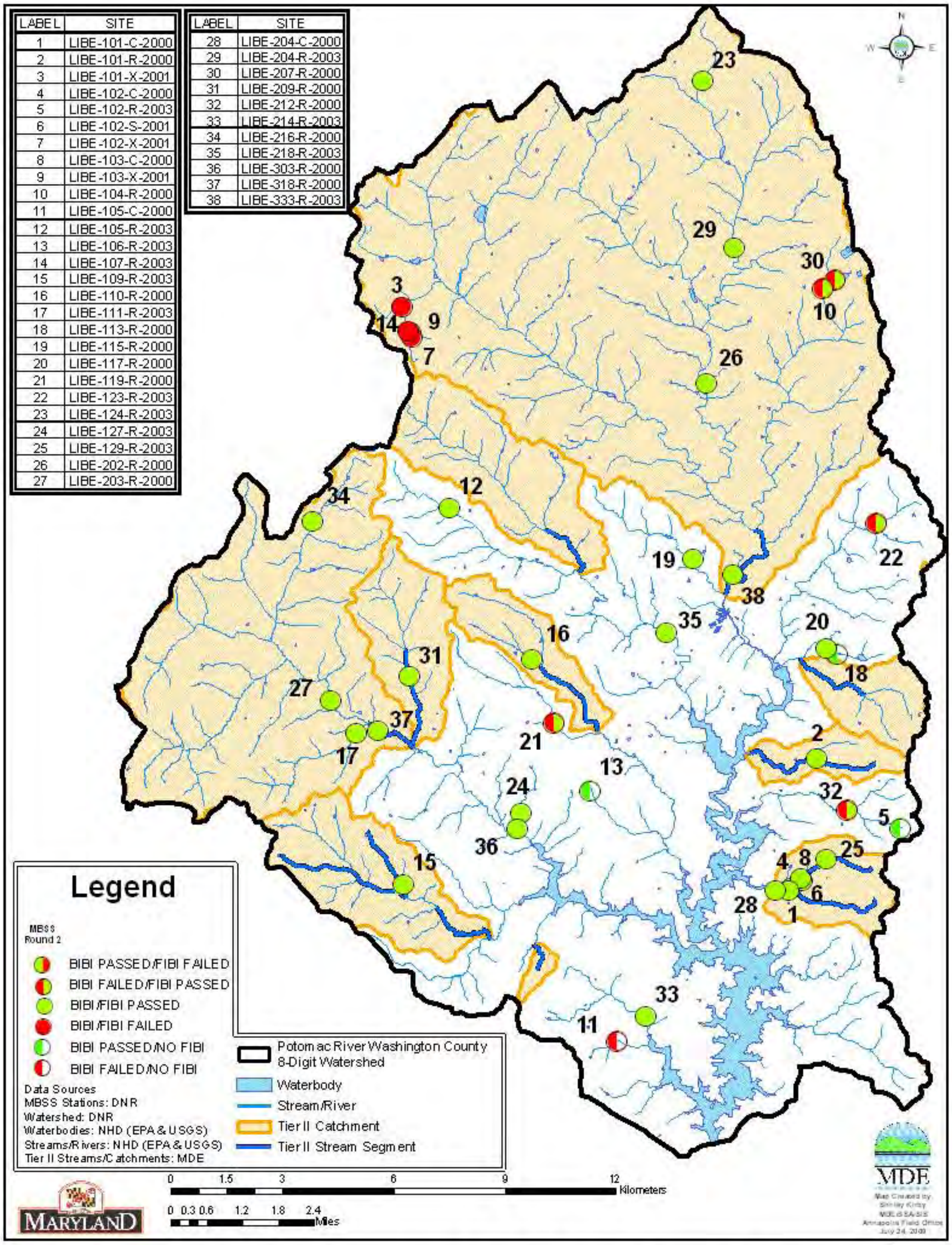

Figure 5. Principal Dataset Sites for the Liberty Reservoir Watershed

4.0 Stressor Identification Results

The BSID process uses results from the BSID data analysis to evaluate each biologically impaired watershed and determine potential stressors and sources. Interpretation of the BSID data analysis results is based upon components of Hill's Postulates (Hill 1965), which propose a set of standards that could be used to judge when an association might be causal. The components applied are: 1) the strength of association which is assessed using the odds ratio; 2) the specificity of the association for a specific stressor (risk among controls); 3) the presence of a biological gradient; 4) ecological plausibility which is illustrated through final causal models; and 5) experimental evidence gathered through literature reviews to help support the causal linkage.

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores significantly lower than 3.0 (i.e., poor to very poor). The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 1st and 2nd-4th order), that have good biological conditions.

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenszel (MH) (1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are poor to very poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and poor to very poor biological conditions and is used to identify potential stressors.

Once potential stressors are identified (i.e., odds ratio significantly greater than one), the risk attributable to each stressor is quantified for all sites with poor to very poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with poor to very poor biological conditions that are a result of the stressor. The AR is calculated as the difference between the proportion of case sites with the stressor present and the proportion of control sites with the stressor present.

Once the AR is calculated for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a group of stressors is also summed over the case sites using the individual site characteristics (i.e., stressors present at that site). The only difference is that the absolute risk for the controls at each site is estimated based on the stressor present at the site that has the lowest absolute risk among the controls.

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the proportion of cases, sites in the watershed with poor to very poor biological conditions, which would be improved if the potential stressors were eliminated (Van Sickle and Paulsen 2008). The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases (MDE 2010).

Through the BSID data analysis, MDE identified water chemistry parameters and potential sources significantly associated with degraded fish and/or benthic biological conditions. As shown in Table 1 through Table 3, parameters from the sediment, habitat, and water chemistry groups, but only parameters from the water chemistry group are identified as possible biological stressors in the Liberty Reservoir watershed. Parameters identified as representing possible sources are listed in Table 4 and include various urban land use types. Table 5 shows the summary of combined attributable risk (AR) values for the stressor groups in the Liberty Reservoir watershed. Table 6 shows the summary of combined attributable risk (AR) values for the source groups in the Liberty Reservoir watershed.

Table 1. Sediment Biological Stressor Identification Analysis Results for the Liberty Reservoir Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata1 with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds or stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Sediment	extensive bar formation present	38	10	90	20%	13%	No	----
	moderate bar formation present	38	10	90	60%	41%	No	----
	bar formation present	38	10	90	100%	90%	No	----
	channel alteration moderate to poor	38	10	90	60%	40%	No	----
	channel alteration poor	38	10	90	0%	12%	No	----
	high embeddedness	38	10	90	0%	8%	No	----
	epifaunal substrate marginal to poor	38	10	90	20%	14%	No	----
	epifaunal substrate poor	38	10	90	0%	3%	No	----
	moderate to severe erosion present	38	10	90	80%	62%	No	----
	severe erosion present	38	10	90	10%	12%	No	----
	poor bank stability index	38	10	90	0%	6%	No	----
	silt clay present	38	10	90	100%	100%	No	----

Table 2. Habitat Biological Stressor Identification Analysis Results for the Liberty Reservoir Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds or stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
In-Stream Habitat	channelization present	38	10	91	10%	9%	No	----
	instream habitat structure marginal to poor	38	10	90	20%	13%	No	----
	instream habitat structure poor	38	10	90	0%	1%	No	----
	pool/glide/eddy quality marginal to poor	38	10	90	50%	53%	No	----
	pool/glide/eddy quality poor	38	10	90	0%	1%	No	----
	riffle/run quality marginal to poor	38	10	90	20%	19%	No	----
	riffle/run quality poor	38	10	90	0%	1%	No	----
	velocity/depth diversity marginal to poor	38	10	90	40%	53%	No	----
	velocity/depth diversity poor	38	10	90	0%	0%	No	----
	concrete/gabion present	38	10	91	0%	1%	No	----
	beaver pond present	38	10	90	0%	4%	No	----
Riparian Habitat	no riparian buffer	38	10	91	20%	25%	No	----
	low shading	38	10	90	10%	8%	No	----

Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Liberty Reservoir Watershed

Parameter Group	Stressor	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with stressor present	% of control sites per strata with stressor present	Possible stressor (Odds of stressor in cases significantly higher than odds or stressors in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor
Water Chemistry	high total nitrogen	38	10	165	80%	47%	Yes	33%
	high total dissolved nitrogen	20	5	56	60%	45%	No	----
	ammonia acute with salmonid present	38	10	165	30%	5%	Yes	25%
	ammonia acute with salmonid absent	38	10	165	30%	3%	Yes	27%
	ammonia chronic with salmonid present	38	10	165	40%	15%	Yes	25%
	ammonia chronic with salmonid absent	38	10	165	30%	4%	Yes	26%
	low lab pH	38	10	165	0%	2%	No	----
	high lab pH	38	10	165	0%	2%	No	----
	low field pH	38	10	164	0%	4%	No	----
	high field pH	38	10	164	0%	2%	No	----
	high total phosphorus	38	10	165	10%	6%	No	----
	high orthophosphate	38	10	165	10%	8%	No	----
	dissolved oxygen < 5mg/l	38	10	164	0%	1%	No	----
	dissolved oxygen < 6mg/l	38	10	164	0%	2%	No	----
	low dissolved oxygen saturation	35	10	152	0%	1%	No	----
	high dissolved oxygen saturation	35	10	152	0%	0%	No	----
	acid neutralizing capacity below chronic level	38	10	165	0%	1%	No	----
	acid neutralizing capacity below episodic level	38	10	165	0%	7%	No	----
	high chlorides	38	10	165	60%	5%	Yes	55%
	high conductivity	38	10	165	50%	6%	Yes	44%
	high sulfates	38	10	165	10%	4%	No	----

Table 4. Stressor Source Identification Analysis Results for the Liberty Reservoir Watershed

Parameter Group	Source	Total number of sampling sites in watershed with stressor and biological data	Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI)	Controls (Average number of reference sites per strata with fair to good Fish and Benthic IBI)	% of case sites with source present	% of control sites per strata with source present	Possible stressor (Odds of stressor in cases significantly higher than odds or sources in controls using p<0.1)	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source
Sources Urban	high impervious surface in watershed	38	10	164	50%	3%	Yes	47%
	high % of high intensity urban in watershed	38	10	165	90%	21%	Yes	69%
	high % of low intensity urban in watershed	38	10	165	40%	5%	Yes	35%
	high % of transportation in watershed	38	10	165	60%	9%	Yes	51%
	high % of high intensity urban in 60m buffer	38	10	164	50%	4%	Yes	46%
	high % of low intensity urban in 60m buffer	38	10	164	40%	6%	Yes	34%
	high % of transportation in 60m buffer	38	10	164	20%	6%	No	----
Sources Agriculture	high % of agriculture in watershed	38	10	165	0%	22%	No	----
	high % of cropland in watershed	38	10	165	0%	3%	No	----
	high % of pasture/hay in watershed	38	10	165	0%	29%	No	----
	high % of agriculture in 60m buffer	38	10	164	10%	13%	No	----
	high % of cropland in 60m buffer	38	10	164	0%	3%	No	----
	high % of pasture/hay in 60m buffer	38	10	164	30%	23%	No	----
Sources Barren	high % of barren land in watershed	38	10	165	0%	10%	No	----
	high % of barren land in 60m buffer	38	10	164	0%	10%	No	----
Sources Anthropogenic	low % of forest in watershed	38	10	165	70%	8%	Yes	62%
	low % of forest in 60m buffer	38	10	164	80%	9%	Yes	71%
Sources Acidity	atmospheric deposition present	38	10	165	0%	5%	No	----
	AMD acid source present	38	10	165	0%	0%	No	----
	organic acid source present	38	10	165	0%	0%	No	----
	agricultural acid source present	38	10	165	0%	2%	No	----

Table 5. Summary of Combined Attributable Risk Values of the Stressor Group in the Liberty Reservoir Watershed

Stressor Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Sediment	----	75%
Instream Habitat	----	
Riparian Habitat	----	
Water Chemistry	75%	

Table 6. Summary of Combined Attributable Risk Values of the Source Group in the Liberty Reservoir Watershed

Source Group	Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk)	
Urban	83%	84%
Agriculture	----	
Barren Land	----	
Anthropogenic	72%	
Acidity	----	

Sediment Conditions

BSID analysis results for the Liberty Reservoir watershed did not identify sediment parameters that have statistically significant associations with poor to very poor stream biological condition.

Instream Habitat Conditions

BSID analysis results for the Liberty Reservoir watershed did not identify instream habitat parameters that have statistically significant associations with poor to very poor stream biological condition.

Riparian Habitat Conditions

BSID analysis results for the Liberty Reservoir watershed did not identify riparian habitat parameters that have statistically significant associations with poor to very poor stream biological condition.

Water Chemistry

BSID analysis results for the Liberty Reservoir watershed identified seven water chemistry parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community). These parameters are ***high total nitrogen, acute ammonia (with salmonid present and salmonid absent), chronic ammonia (with salmonid present and salmonid absent), high chlorides, and high conductivity.***

High total nitrogen (TN) concentrations are significantly associated with degraded biological conditions and found in 33% of the stream miles with poor to very poor biological conditions in the Liberty Reservoir watershed. This stressor is a measure of the amount of TN in the water column. TN is comprised of organic nitrogen, ammonia nitrogen, nitrite and nitrate. Nitrogen plays a crucial role in primary production. Elevated levels of nitrogen can lead to excessive growth of filamentous algae and aquatic plants. Excessive nitrogen input also can lead to increased primary production, which potentially results in species tolerance exceedences of dissolved oxygen and pH levels. Runoff and leaching from agricultural land can generate high in-stream levels of nitrogen.

Ammonia (NH_3) *acute* concentrations were identified as significantly associated with degraded biological conditions in Liberty Reservoir watershed, and found to impact approximately 25% (*with salmonid present*) and 27% (*with salmonid absent*) of the stream miles with poor to very poor biological conditions. Acute NH_3 toxicity refers to potential exceedences of species tolerance caused by one-time, sudden, high exposure of NH_3. NH_3 acute with salmonid present and absent is a USEPA water quality criterion for NH_3 concentrations causing acute toxicity in surface waters where salmonid species of fish are present and absent (USEPA 2006). The NH_3 parameter is the measure of the amount of NH_3 in the water column. NH_3 is a nitrogen nutrient species; in excessive amounts it has potential toxic effects on aquatic life. NH_3 is associated with increased primary production, increased pH, increased sunlight exposure, and high water temperature. Increased nutrient loads from urban and agricultural development are a source of NH_3.

Ammonia chronic concentrations were identified as significantly associated with degraded biological conditions in Liberty Reservoir watershed, and found to impact approximately 25% (*with salmonid present*) and 26% (*with salmonid absent*) of the stream miles with poor to very poor biological conditions. Chronic NH_3 toxicity refers to potential exceedences of species tolerance caused by repeated exposure over a long period of time, see USEPA 2006 reference.

Non-point source discharges are a potential source of pollutants (e.g., nutrient and suspended solids) to surface waters; they do not have one discharge point but occur over the entire length of a stream or waterbody. During rain events, surface runoff transports water over the land surface and discharges to the stream system. This transport is dictated by rainfall, soil type, land use, and topography of the watershed. The Liberty Reservoir watershed is comprised of 27% urban land use, it is located in Baltimore and Carroll Counties, both counties have individual National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permits. An MS4 is a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) designed or used for collecting or conveying stormwater and delivering it to a waterbody. Stormwater runoff is an important source of water pollution;j MS4 programs are designed to reduce the amount of pollution that enters a waterbody from storm sewer systems to the maximum extent feasible. Roads tend to capture and export more stormwater pollutants than other land covers; as rainfall amounts become larger, previously pervious areas in most residential areas become more significant sources of runoff, sediment, nutrients, and landscaping chemicals (NRC 2008). Statements and information provided to MDE by the two Counties characterize much of the Liberty Reservoir watershed as essentially outside the reach of each County's stormwater system management plan (with the exception of the Westminster, Hampstead, and Manchester Phase II areas, and the Eldersburg Phase I urban area) (MDE 2008).

Non-point source contributions also arise from failing septic systems and their associated drain fields or from leaking infrastructure (i.e., sewer systems) (MDE 2008). The Liberty Reservoir watershed is serviced by both sewer systems and septic systems. Sewer systems are either present or planned in the towns of Westminster, Manchester, Hampstead, and Eldersburg, but the wastewater treatment plants (WWTPs) for these towns do not fall within the Liberty Reservoir watershed. On-site disposal (septic) systems are located throughout the Liberty Reservoir basin (MDE 2008). In urban areas such as Baltimore City that feature combined storm and sewer drains, high flow events result in elevated bacterial and nutrient levels, including potentially lethal concentrations of ammonia.

There are thirty-eight MBSS stations in the Liberty Reservoir watershed and minimal sampling for ammonia was conducted (onetime sample) at each station. Acute ammonia toxicity refers to potential exceedences of species tolerance caused by a one-time, sudden, high exposure of ammonia. However, chronic ammonia toxicity refers to potential exceedences of species tolerance caused by repeated exposure over a long period of time. To make an accurate determination of acute and chronic ammonia toxicity, MDE reviewed additional data to determine if there is ammonia toxicity impairment in these waters. During the years of 1999, 2000, 2003, 2004, 2005 and 2007, MDE collected one thousand six hundred and four water quality samples from the Liberty Reservoir watershed. Samples were collected at twenty-nine stations through out the watershed, with most stations being sampled monthly for approximately a year. None of the samples showed exceedances of any of the four USEPA and MDE criteria for ammonia: acute criterion when salmonid fish are present, acute criterion when salmonid fish are absent, chronic criterion when early life stages are present or chronic criterion when early life stages are absent (USEPA 2006). Due to these results from the MDE water quality data analysis, it was determined that ammonia toxicity is not a widespread problem in the Liberty Reservoir watershed.

The atmosphere can contribute various forms of nitrogen arising from the burning of fossil fuels and from automobile exhaust (MDDNR 2002a). According to MDDNR 2002a, the Liberty Reservoir watershed is among those with a high to excessive TN concentration based on data from one "core" non-tidal stream monitoring station in the watershed. Watersheds were ranked on a 1 (worst) to 10 (best) scale to allow comparison of TN among them using the Tributary Team reporting methods for status/trends; Liberty Reservoir watershed was ranked "2" for TN (MDDNR 2002a). In Wisconsin streams, Wang et al. (2006) found that many macroinvertebrate and fish measures were significantly correlated with nitrogen concentrations, implying that nutrients have direct and/or indirect links with those biological assemblages.

Agriculture is the dominant land use (39%) within the Liberty Reservoir watershed. Agricultural land use is an important source of pollution when rainfall carries sediment, fertilizers, manure, and pesticides into streams. One of the three major nutrients in fertilizers and manure is nitrogen. Livestock waste is one of the primary agricultural sources of TN; it is a greater contributor than commercial fertilizer (USEPA 2000). Developed landscapes, particularly the proportion of agriculture in the catchments and the riparian zone, often results in increased inputs of nitrogen to surface waters. The MDDNR MBSS data did not include photographs of cow access to streams, and only a few comments regarding cows in a stream and cow pastures. Most of the nutrient loads in the Liberty Reservoir watershed appear to be coming from non-point sources because point sources of nitrogen in the watershed are small (MDDNR 2002a).

Identification of high TN and NH_3 toxicity by the BSID analysis are possibly indicative of degradation to water quality, but in conditions of excessive nutrient loading (i.e., eutrophication), pH and/or dissolved oxygen are also affected; this result does not support a case of excessive nutrient loading in the Liberty Reservoir watershed. MDE considers phosphorus to be the limiting nutrient species in an ecosystem. Phosphorus is generally much less soluble than nitrogen; it is leached from the soil at a much slower rate than nitrogen. Consequently, phosphorus is much more important as a limiting nutrient in aquatic systems (Smith, Tilman, and Nekola 1999). A TN:TP ratio analysis of five years of MDE data was completed for the Liberty Reservoir watershed confirming that phosphorus is a limiting factor.

High chlorides levels are significantly associated with degraded biological conditions and found in approximately 55% (*high* rating) of the stream miles with poor to very poor biological conditions in the Liberty Reservoir watershed. High concentrations of chlorides can result from industrial discharges, metals contamination, and application of road salts in urban landscapes.

High conductivity concentrations are significantly associated with degraded biological conditions and found in 44% of the stream miles with poor to very poor biological conditions in the Liberty Reservoir watershed. This stressor is a measure of water's ability to conduct electrical current and is directly related to the total dissolved salt content of the water. Stream conductivity is determined primarily by the geology of the area through which the stream flows. Most of the total dissolved salts of surface waters are comprised of inorganic compounds or ions such as chloride, sulfate, carbonate, sodium, and phosphate (IDNR 2008). Urban and agricultural runoffs, e.g. fertilizers, as well as leaking wastewater infrastructure (point sources) are typical sources of inorganic compounds.

There are several NPDES permitted point source discharges in the Liberty Reservoir watershed; since none of the facilities are permitted for chlorides, application of road salts in the watershed is a likely source of the chlorides and high conductivity levels. Although chlorides can originate from natural sources, most of the chlorides that enter the environment are associated with the storage and application of road salt (Smith et al. 1987). For surface waters associated with roadways or storage facilities, episodes of salinity have been reported during the winter and spring in some urban watercourses in the range associated with acute toxicity in laboratory experiments (EC 2001). These salts remain in solution and are not subject to any significant natural removal mechanisms; road salt accumulation and persistence in watersheds poses risks to aquatic ecosystems and to water quality (Wegner and Yaggi 2001).

Currently in Maryland there are no specific numeric criteria that quantify the impact of chlorides and conductivity on the aquatic health of non-tidal stream systems. Since the exact sources and extent of inorganic pollutant loadings are not known, MDE determined that current data are not sufficient to enable identification of the specific pollutant(s) causing degraded biological communities from the array of potential inorganic pollutants loading from urban development.

The Liberty Reservoir watershed is considered a high priority watershed for both restoration and protection, primarily because of its use as a drinking water supply (MDDNR 2002a). The BSID analysis results identify several parameters of water chemistry as significant stressors in the Liberty Reservoir watershed; water chemistry is a major determinant of the integrity of surface waters that is strongly influenced by land-use. Urban land development can cause an increase in contaminant loads from point and non-point sources by adding sediments, nutrients, road salts, toxics, and inorganic pollutants to surface waters. Physical habitats, when exposed to detrimental and chronic water chemistry effects, cease functioning efficiently and degrade.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the water chemistry stressor group is approximately 75% suggesting this stressor impacts a considerable proportion of the degraded stream miles in the Liberty Reservoir watershed (Table 5).

Sources

All seven stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation in the Liberty Reservoir watershed and are representative of impacts from urban developed landscapes. Although agricultural landuse (39%) is the dominant land use in the Liberty Reservoir watershed, the BSID results identified urban development (27%) as significantly (83%) associated with poor to very poor biological conditions in the watershed. Urban land use was identified as significant not only in the watershed but also in the riparian buffer zone. According to a MDDNR assessment (Stranko 2001) of the Liberty Reservoir watershed, the relatively small amount of urbanization and abundance of habitat structure in most of the streams in the Liberty Reservoir watershed is indicative of minimal anthropogenic degradation; the most common kinds of stream degradation encountered were stream bank erosion and insufficient vegetated riparian buffers. MDDNR also reports that non-point source degradation from agricultural and urban development seem to be having the greatest negative influence on the ecology of this watershed (Stranko 2001). There is a small amount of urban development in the watershed; the majority of failing MDDNR MBSS stations are primarily located near the urban regions of the watershed, i.e. Hampstead, Reisterstown, and Westminster. The land use of these stations is influencing the source results of the BSID analysis.

A number of systematic and predictable environmental responses have been noted in streams affected by urbanization, and this consistent sequence of effects has been termed "urban stream syndrome" (Meyer et al. 2005). In watersheds already experiencing anthropogenic stress, hydrologic variability is exacerbated by urbanization, which increases the amount of impervious surface in a basin and causes higher overland flows to streams, especially during storm events (Southerland et al. 2005b). Due to the increase in impervious surface cover that is associated with urbanization, pollutants (e.g., inorganics, nutrients) are more readily delivered to a stream by surface runoff. According to Wang et al. 2001, even under the best-case urban development scenarios, stream fish communities will decline substantially in quality even while a watershed remains largely rural in character.

According to Forman and Deblinger (2000), there is a "road-effect zone" over which significant ecological effects extend outward from a road; these effects extend 100 to 1,000 m (average of 300 m) on each side of four-lane roads. Roads tend to capture and export more stormwater pollutants than other land covers; as rainfall amounts become larger, previously pervious areas in most residential landscapes become more significant sources of runoff (NRC 2008). According to the Liberty Reservoir Watershed Characterization report (MDDNR 2002a), on average 6.3% of the watershed surface cover is impervious, this exceeds the MDDNR MBSS limit of 4% for streams that rate "Fair" to "Good" for both fish and instream invertebrates. BSID results also identified transportation in the watershed as related to degraded stream miles (51%) in the Liberty Reservoir watershed. Interstate 795, and other State and county paved roads interconnect points within the region, routes 26 and 140 pass directly over the Liberty Reservoir impoundment. A strong relationship was established between increasing chloride levels and increasing road density (MDDNR 2002a). A likely source of these results is de-icing agents (i.e., road salts) used on roads and parking lots, which wash off of these surfaces during rain events into adjacent stream systems (MDDNR 2002a).

MDDNR also identified a significant increase in chloride levels and increasing conductivity readings since 1992; conductivity values serve as a suitable substitute when chloride values are absent (MDDNR 2002a). Several relationships were explored to determine the most likely causes of this increasing trend; the strongest relationship occurred between increasing chloride values and the amount of commercial and industrial land use. Typically, these land uses have very high percentages of impervious surfaces for parking and buildings. Fertilizers (e.g., potassium nitrate) from landscaping runoff from residential lawns, golf courses, and athletic fields, are also a source of salts. Fertilizer salts are soluble, they readily dissolve in water and leach with rainfall, in excess quantities salts can increase instream conductivity. Extended dry periods and low flow conditions also contribute to higher conductivity results. Conductivity levels may also be natural; the MDDNR WRAS synoptic (2002b) states that conductivity anomalies in four sub-watersheds (i.e., Snowden Run, Middle Run, Roaring Run and West Branch) were attributed to natural biological processes in the Carroll County portion of the Liberty Reservoir watershed.

The BSID source analysis (Table 4) identifies various types of urban land uses as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 83% suggesting that these stressors impact a substantial proportion of the degraded stream miles in Liberty Reservoir watershed (Table 6).

Summary

The BSID analysis results suggest that degraded biological communities in the Liberty Reservoir watershed are a result of increased urban land uses causing alteration to hydrology, resulting in an unstable stream ecosystem that eliminates habitat heterogeneity. High proportions of these land uses also typically result in increased contaminant loads from point and non-point sources by adding inorganic pollutants and nutrients to surface waters, resulting in levels that can potentially be toxic to aquatic organisms. Alterations to the hydrologic regime and water chemistry; have all combined to degrade the Liberty Reservoir watershed, leading to a loss of diversity in the biological community. The combined AR for all the stressors is approximately 75%, suggesting that water chemistry stressors and altered hydrology (e.g., roads, impervious surfaces) adequately account for the biological impairment in the Liberty Reservoir watershed.

The results of this analysis are not intended or implied to be absolute and unchanging. However, the results do configure the most probable pathway for biological impairment using the highest quality data currently available. BSID analysis evaluates numerous key stressors that could act independently or act as part of complex causal scenarios (e.g., eutrophication, urbanization, habitat modification). In this process, absence of a key stressor(s) can be as important as the presence of stressors to ultimately determine impairment causation. Uncertainty resulting from basic limitations of the principal dataset (e.g., temporal and spatial variability, sample size) is reduced, but not eliminated in BSID.

Final Causal Model for the Liberty Reservoir Watershed

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr 1991; USEPA 2009). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 6 illustrates the final casual model for the Liberty Reservoir watershed, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

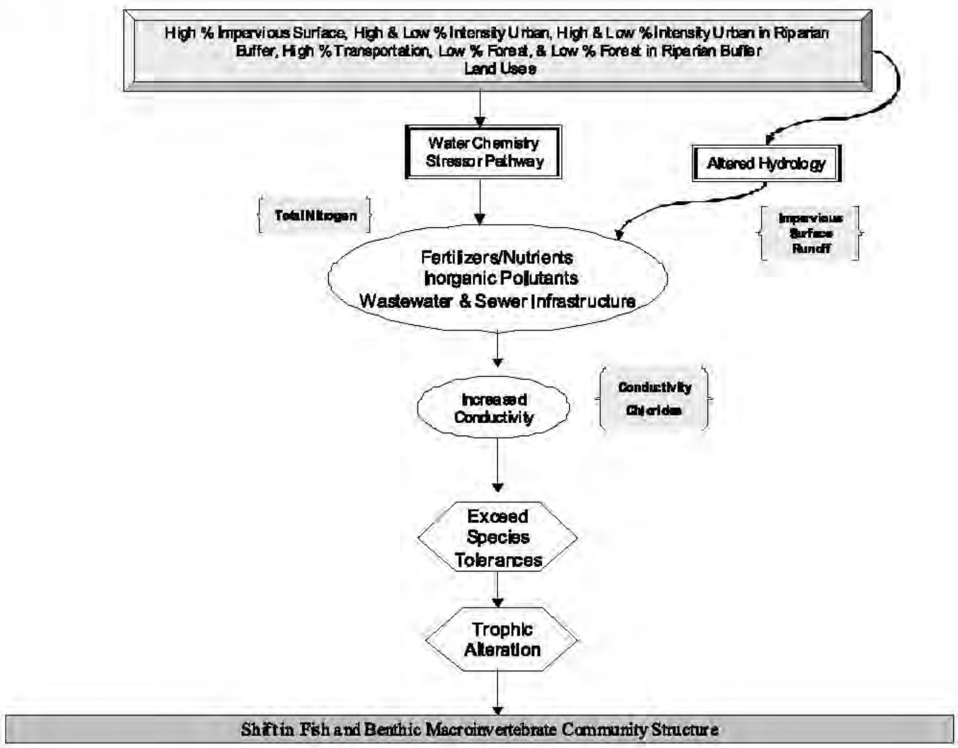

Figure 6. Final Causal Model for the Liberty Reservoir Watershed

5.0 Conclusions

Data suggest that the Liberty Reservoir watershed's biological communities are strongly influenced by urban land use, which alters the hydrologic regime resulting in increased nutrient and inorganic pollutant loading. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to urban landscapes, which often cause flashy hydrology in streams and increased contaminant loads from runoff. Based upon the results of the BSID process, the probable causes and sources of the biological impairments of the Liberty Reservoir watershed are summarized as follows:

- The BSID process has determined that the biological communities in the Liberty Reservoir watershed are likely degraded due to inorganic pollutants (i.e., chlorides). Chloride levels are significantly associated with degraded biological conditions and found in approximately 55% of the stream miles with poor to very poor biological conditions in the Liberty Reservoir watershed. Impervious surfaces and urban runoff cause an increase in contaminant loads from point and nonpoint sources by delivering an array of inorganic pollutants to surface waters. Discharges of inorganic compounds are very intermittent; concentrations vary widely depending on the time of year as well as a variety of other factors may influence their impact on aquatic life. Future monitoring of these parameters will help in determining the spatial and temporal extent of these impairments in the watershed. The BSID results thus support Category 5 listing of chloride for the watershed.
- There is presently a Category 5 listing for phosphorus (impoundment) in Maryland's 2010 Integrated Report; BSID analysis identified TN, not phosphorus, as a potential water chemistry stressor in the Liberty Reservoir watershed. The presence of TN in the Liberty Reservoir watershed shows a possible association (33% of stream miles) with degraded biological conditions. Because nitrogen generally exists in quantities greater than necessary to sustain algal growth, excess nitrogen per se is not the cause of the biological impairment in the Liberty Reservoir watershed. MDE considers phosphorus to be the limiting nutrient species in an ecosystem, and since phosphorus was not identified as a potential stressor, reduction of nitrogen loads would not be an effective means of ensuring that the watershed is free from impacts on aquatic life from eutrophication.

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